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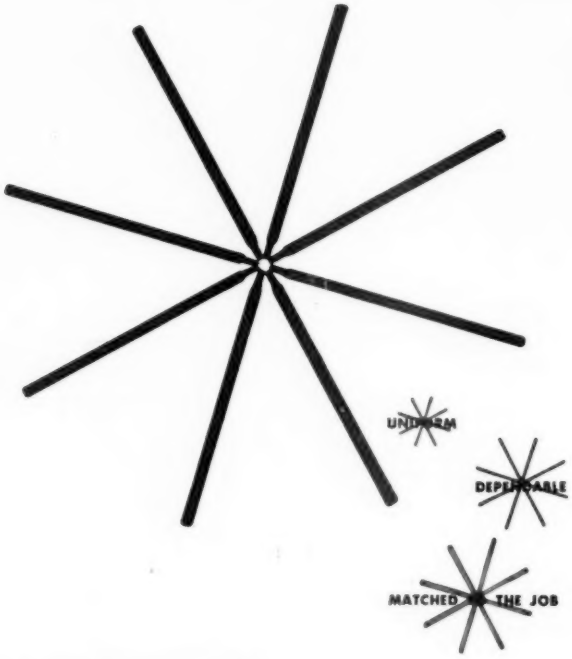

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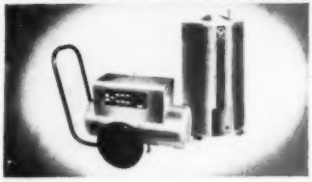

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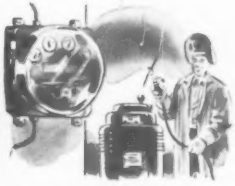

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cover: Manufacture of low pressure galvanized steel acetylene generators. Courtesy L. O. Koren & Brother, Inc.

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Specialized Steel Mill Cutting Machines and Controls

In recent years, equipment and controls to handle hot materials on or off the roll line has made its appearance and is described in this paper as well as gas supply and control systems

by R. F. Helmkamp and A. H. Yoch

INTRODUCTION

STEEL mill production is hitting new highs continuously. We are at a point now where production exceeds that of the war years. Many of the products considered necessary for our way of life are in short supply since the manufacturers of finished products are, in a sense, still rationed as far as steel is concerned. This in itself imposes a restriction reflected in high prices from the standpoint of supply and demand, but basic prices have also risen due to our present economic position and government rulings. This set of conditions, as always, causes the producer and the engineer to constantly check new processes and developments and new applications of older processes to develop whether or not, time, cost per unit, operating cost maintenance and capital investment show an advantage over present established practice.

The gas cutting process is growing up; it is beyond the crawling stage and constant investigation of its possibilities and dependability has developed applications that are now considered commonplace. In recent years, equipment and controls to handle hot materials on or off the roll line has made its appearance. Before this was practical, however, the gas supply problem had to be met. Gas supply and control systems are now available for the present stage of development of cutting requirements.

Hot cutting and especially production cutting called for a higher degree of mechanization of the process. It is not strange, therefore, to find electronics being employed as motor speed controls, template tracers and arrangements to keep cutting tips at a constant height from the workpiece no matter what its contour may be. Other problems to be met were remote controls, automatic controls, heat protection for equipment and operators, fume control and disposal and slag disposal. To date a good start has been made on all of these problems and highly specialized machines have been built incorporating these features.

Gas cutting is not a cure-all for any and all problems, it has some drawbacks and some advantages. The problem is to find its place where it can hold its own based on performance and acceptable results. Alloy steels may be cut cold for such operations as scrapping but for production work such steels should be cut at elevated temperatures. Knowledge developed experimentally indicates that the speed of gas cutting increases as the temperature rises, the high speeds, however, are attained above the critical of the material. This fact assists in making gas cutting suitable economically for some roll line operations, forging and foundry work. Various types of plate work are also accomplished by hot cutting—a good example is the work being done on soft center steel plate for agricultural equipment. Thus a better understanding of the factors involved broadens the uses of gas cutting.

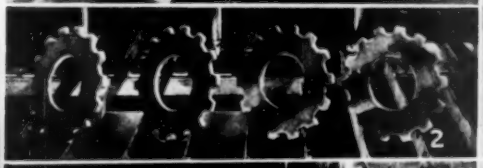
MACHINES

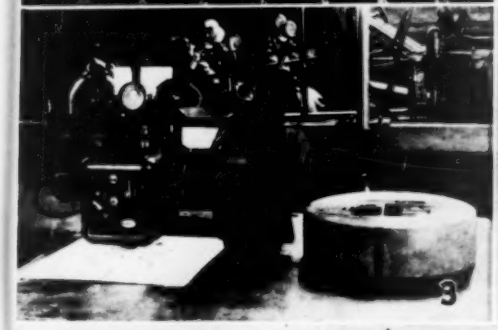
Gas cutting machines are available as highly portable equipment, also stationary and for highly specialized, high-production applications. All such machines are motor-driven with variable speed controls. The portable machines are manually controlled while the other types are both manually controlled and also automatically controlled throughout a given cycle. The automatic controls are generally found on the high-production, highly specialized machines.

The stationary type of cutting machine is generally of the pantograph type and has a width and length area to suit present industrial requirements. The tracer mechanisms for these machines are somewhat varied and range from the electronic tracer, which will follow an outline drawing or a paper cutout, to the old familiar manual tracer.

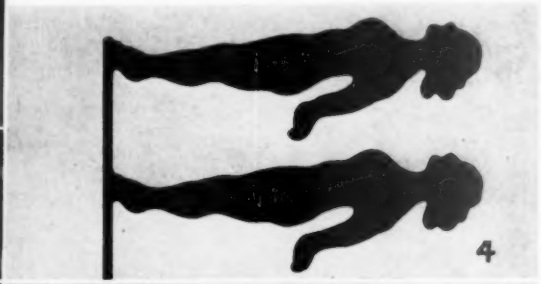
R. F. Helmkamp and **A. H. Yoch** are Machine Cutting Specialists, Technical Sales Division, Air Reduction Sales Co., New York, N. Y.

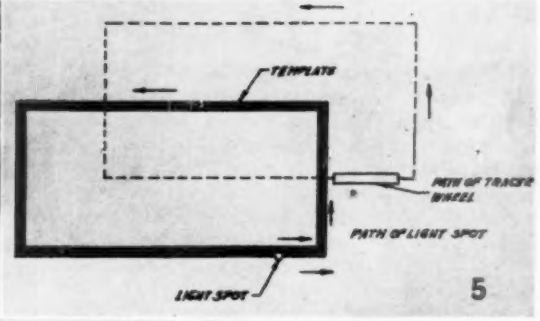
This paper was presented at the Twenty-Ninth Annual Meeting, A.W.S., Philadelphia, Pa., week of Oct. 24, 1948.

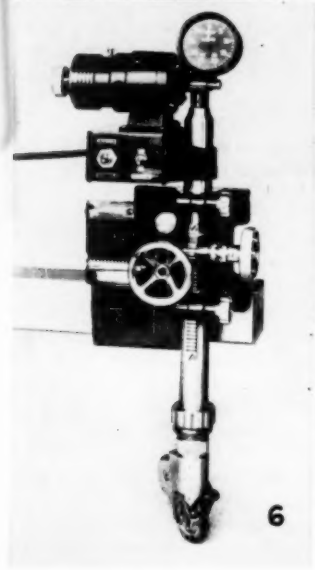


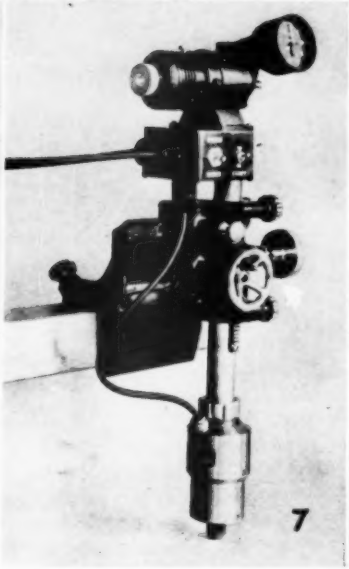


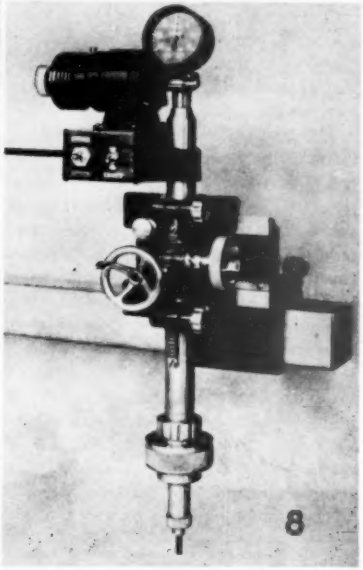
1. Electronic tracing device mounted on a stationary type cutting machine with four torches cutting sprocket blanks. 2. Four sprocket blanks (Fig. 1) as cut, using electronic tracer and contrasting color paper template. 3. Electronic tracer setup as used for a 5-in. thick extrusion die backer. 4. Template for cutting continuous repetitive shapes with bridging member (bottom) which carries the cut along, yet permits complete severance of individual pieces. 5. Diagrammatic view of the relative positions of the light spot and driving wheel of the electronic tracer. 6. Manual tracing unit as used on shape cutting machines. 7. Magnetic tracer substitutes magnetic holding power against a steel template for manual steering. 8. Spindle type tracer is held manually against template edge.



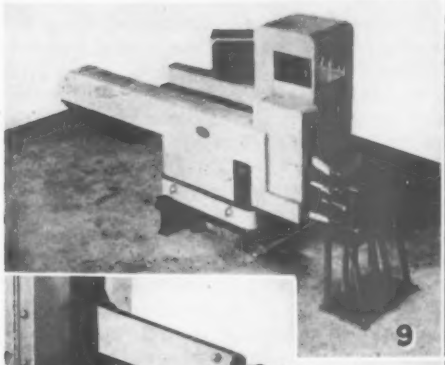


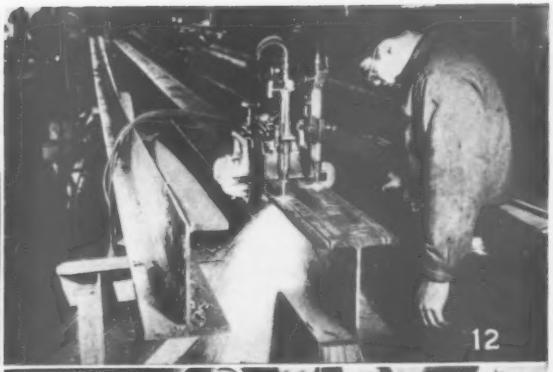


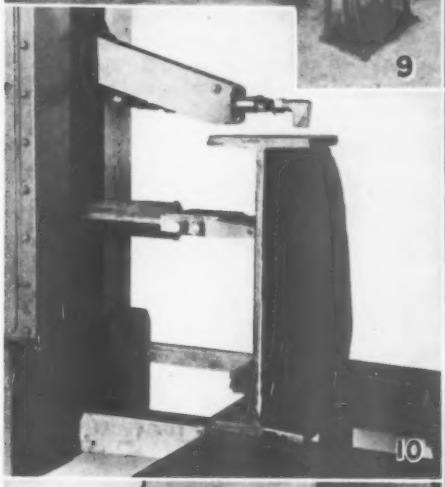


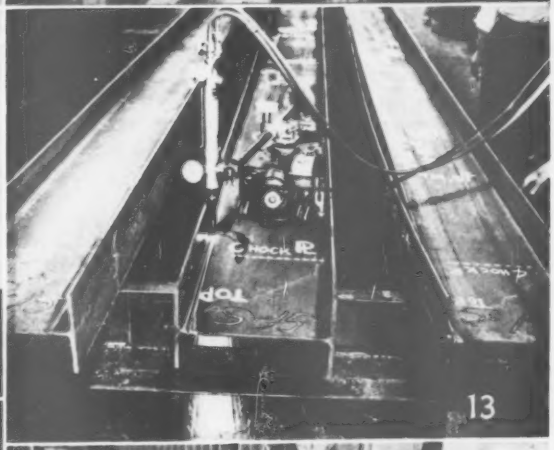


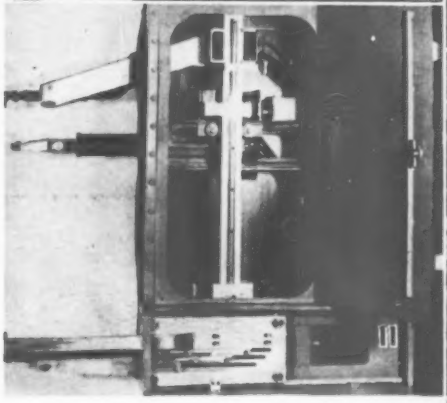
Figs. 1–8

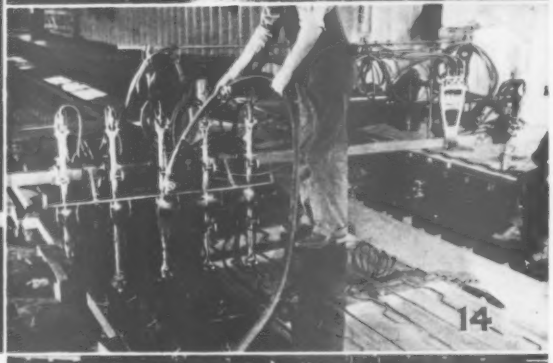












Figs. 9–15

9. Automatic oxyacetylene cutting machine for structural shapes. 10. Three torches of automatic machine (Fig. 9) cut both flanges and web in one operation. 11. Travel and size adjustments for automatic I-beam cutting (Figs. 9 and 10) are made by simple settings. 12. Portable machine produces long-legged tee and unequal flange section from similar beams. 13. Simple adaptation of standard portable machine used to produce long-legged tee from standard beam section. 14. Multiple splitting and notching work, using large-area shape-cutting machine, on channel iron. 15. A quantity of welded subassemblies made up of gas-cut structural members.

Figure 1 shows an electronic tracing device mounted on a stationary type shape-cutting machine. The electronic tracer light beam follows an outline drawing or a paper cut out where sufficient color contrast is provided. Here, four torches cut the desired shape to size simultaneously (Fig. 2). Reproduction of successive like pieces is assured with this type of tracing device at a minimum of template cost. Template storing for future use becomes a simple filing job.

In Fig. 3, we have a close-up of the electronic tracer, showing the simple controls and the driving steering and raising and lowering motors. The cut piece is a 5-in. thick extrusion die backer. The outline drawing of the contrasting color, for this operation, is in position beneath the electronic tracer.

With the electronic tracer it is very practical to do continuous production cutting of like, or dissimilar pieces by making a continuous template with bridging members to carry the cut along, yet allow the pieces to be completely severed. Consideration must be given to kerf widths of the cutting tip being used when laying out a template for such work. The strip from toe to heel of the bathing beauty template in Fig. 4 is the bridging member referred to.

The electronic tracer follows the outline of the template by means of a light spot, maintained half on each of the contrasting colors of the template. The light spot following the template directs the driving motor. The drive wheel which contacts the tracer table actuates the pantograph assembly of the cutting machine to reproduce a like contour at the torch. Figure 5 is a diagrammatic view of the relative positions of the light spot and the driving wheel. Since the drive wheel crosses the template, in some cases, it is desirable to cover the template with a transparent plastic.

Perhaps the oldest and most common tracer used on shape cutting machines is the manual type as represented in Fig. 6. Incidentally, the electronic tracer is built around such a unit. Used manually, the operator steers it, following the drawing; in the electronic version the tiny light spot governs a motor that does the steering.

The magnetic tracer, Fig. 7, is the same general type of unit except that the manual tracer head has been replaced with a magnetic type. An electromagnet provides magnetic holding power against a steel template. The drive motor revolves the knurled roller, thus following the steel template contour to reproduce a like piece at the torch.

Another tracer, known as the spindle type, Fig. 8, consists of a vertically fluted spindle which is held manually against a plywood or similar template. The vertical fluting of the roller affords the driving medium.

Special-purpose machines find a place when production is high enough to warrant the cost involved. A few of the present applications are for the cutting of structural members, beam ripping to produce special beam sections, slab ripping to produce billets, plate slitting to desired widths, cutting any type of opening in some circular members, bar pointing for cold drawing mills, hot cutting on roller lines for any rolled, or forged shape, cropping and cutting billets to length and cutting forging slugs.

Figure 9 is a side view of a structural beam cut-off machine designed to cut both flanges and the web of beams simultaneously. Three torches are used for this operation. The torch end (Fig. 10) of the structural cut-off machine shows the three torches in operating position for cutting the top and bottom flange and the web. In Fig. 11 are shown the control settings that take care of the beam flange and web sizes.

On many fabricated jobs, special beam sections are required. Figure 12 shows a long-legged tee made from a beam and an unequal flange section produced from a like beam by a portable machine.

Another simple adaptation of a standard portable machine (Fig. 13) also produces a long-legged tee from a standard beam section.

Figure 14 illustrates a splitting and notching production job on channel iron. The work is being done in multiple on a large area shape-cutting machine. A water spray assists in lessening distortion of the cut pieces.

In Fig. 15 we have a quantity of welded subassemblies made up of gas-cut structural members.

One method of cutting fits on matching plates is shown in Fig. 16. A portable cutting machine mounting two torches is used to cut the matching edges of two separate plates at the same time.

Figure 17 shows the trimming of a welded corrugated plate assembly. A portable gas cutting machine equipped with a special floating trailer accomplishes the job.

A common requirement for beveling of plate edges calls for two or three torch operations (Fig. 18) to produce a double bevel, bevel and a land, or a bevel (double) and a land. This vertical floating arrangement mounts two to three torches and controls for such purposes.

For converting slabs into billets a special ten torch machine (Fig. 19) serves the purpose at a minimum cost. Slabs, 4 and 6 in. in thickness are cut into billets with this machine. Another version of a multiple torch machine for parallel straight line cutting, mounting five torches for a special requirement appears in Fig. 20.

HEAVY CUTTING

Heavy cutting is a process that really is a time and money saver. It is used on special jobs saving many hours of machining time and makes this type of job practical where otherwise the cost might rule it out. Another version of heavy cutting is the scrapping of large sections, also spills and skulls resulting from steel mill practice.

Heavy cutting is generally done with a machine but hand equipment is also available for this purpose and is very useful on many jobs. Ofttimes it is used to prove the feasibility of a job which will later be done with a machine. Figure 21 shows a 5-ft. long, heavy-duty hand torch equipped with a sling and harness which the operator wears over his shoulder.

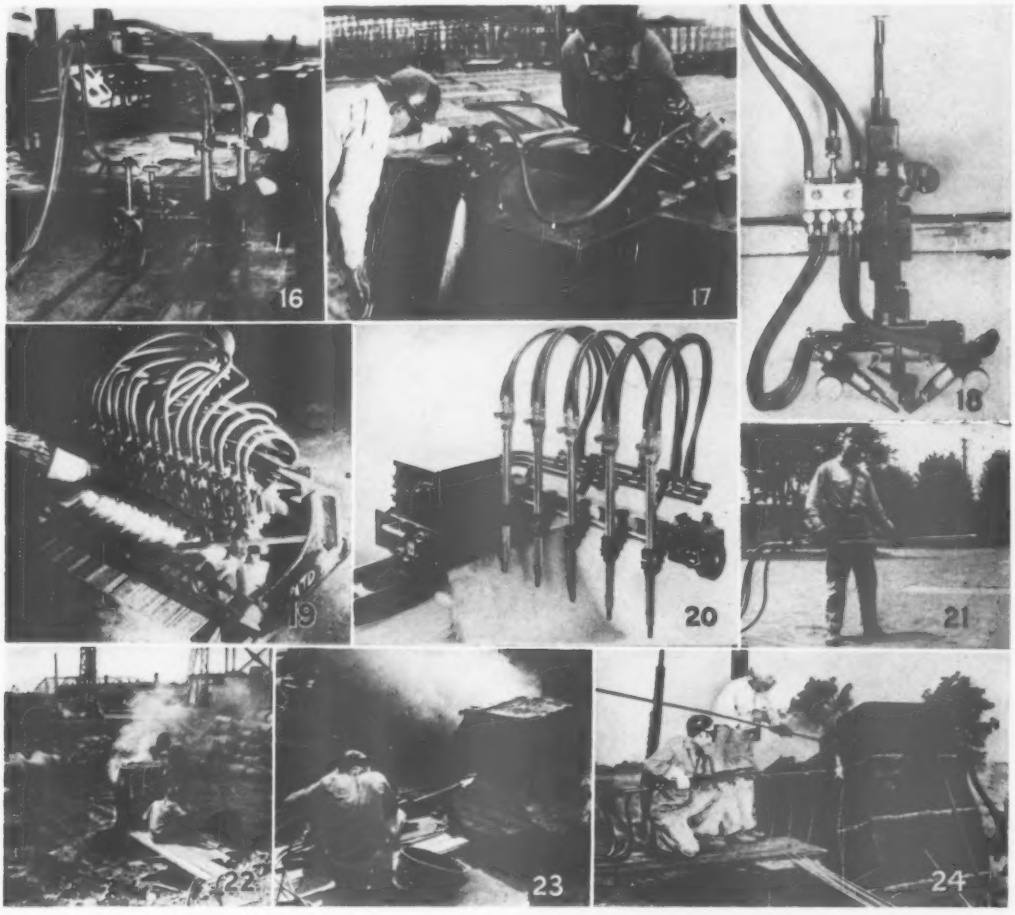
To meet a certain requirement on special castings one portion was cast considerably oversize. Gas cutting (Figs. 22 and 23) quickly roughs the casting to the desired contour. This proved many times faster than machining and much less costly, as large sections of metal were quickly removed with the torch plus a lance on this experiment.

Heavy scrapping operations are sometimes required under conditions with limited facilities. A 50-ton anvil block (Figs 24–26) was in an open field where it had been for about 16 years. It was cut into 20 pieces, 18 x 18 x 48 in. with a hand torch and a lance.

The large special-purpose gas cutting machines call for remote controls. For example, in Fig. 27 we have all of the gas regulators and electric controls, for the drive and solenoid valves, concentrated within easy access of the operator at his station, and Fig. 28 is another set of electric controls grouped for ease of manipulation, and in Fig. 29, the gas controls consisting of regulators, valves and pressure gages are panel-mounted for easy access.

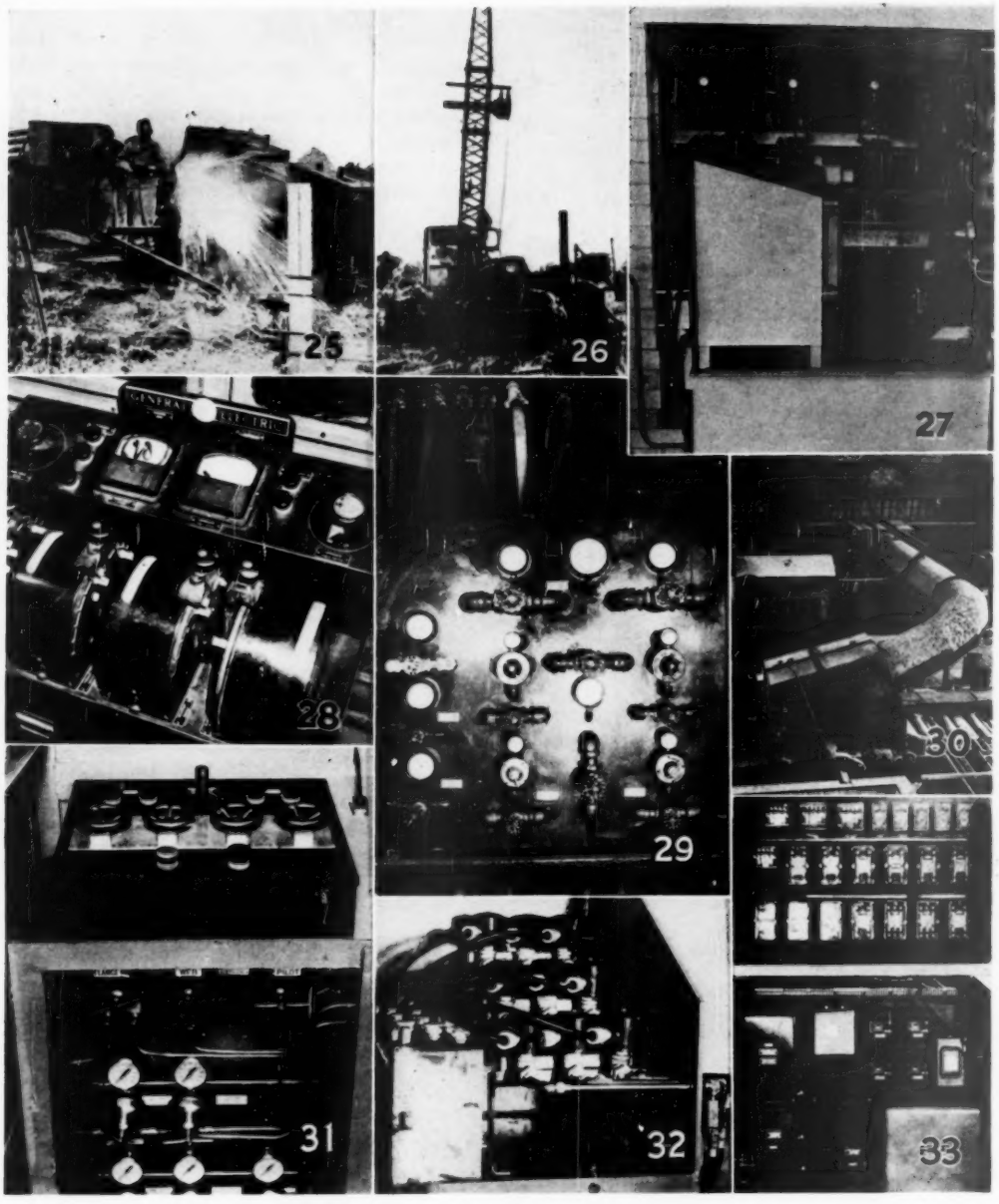
Fume disposal on large and continuous operations is a necessary control feature. In the case shown in Fig. 30, fumes are collected, metallic particles precipitated and the fumes finally discharged through a stack.

In the installation shown in Fig. 31 the operator's control desk has the electric controls on the top and a dual set of regulator controls at the bottom. This centralizes all controls at one location.



Figs. 16–24

16. Cutting fits on matched plates with two torches on a portable machine. 17. Portable machine with special floating trailer used to trim a corrugated plate assembly. 18. Vertical floating arrangement mounting two or three torches and controls for multibeveling operations on plate edges. 19. Ten-torch machine for cutting slabs into billets. 20. Five torches, for a special job, mounted on a multiple torch machine. 21. Five-foot, heavy-duty hand torch equipped with sling and harness. 22. Gas cutting to rough an oversize casting to contour. 23. Work in progress on casting (Fig. 22), using torch and a lance. 24. Fifty-ton anvil block, after 16 years in a field, scrapped by flame-cutting.



Figs. 25–33

25. Completion of the cut on the first section of 50-ton anvil block. Portable gas supply system in rear. 26. Portable crane with magnet, lifting away the first of twenty 2½-ton sections of anvil block. 27. Gas regulators and all controls for the drive and gas solenoids, concentrated at operator's station of a large special-purpose cutting machine. 28. Electric controls grouped for ease of operation in special machine work. 29. Gas controls—regulators, valves, pressure gages—panel-mounted for easy access. 30. Fume disposal installation for a large-scale continuous operation. 31. This control desk has electric controls on top and dual regulator controls at bottom, all centralized in one unit. 32. Gas valves, remotely controlled, are here grouped together in a convenient location. 33. Complete cycle controls for automatic structural-shape cut-off machine housed in one cabinet.

Remote controls for gases are generally handled with solenoid valves. The group shown in Fig. 32 represents nesting of all gas valves, which are remotely controlled.

Fully automatic complete cycle controls require considerable electrical equipment. Figure 33 illustrates such an arrangement on a highly specialized machine completely housed in one cabinet.

CONCLUSION

By comparison with other methods of accomplishing desired results, gas cutting is often able to do the job on a comparable cost-and-time basis. The initial investment cost is usually much less and the equipment oftimes may be located in the production line at a more strategic point. Some industries have started with gas-cutting equipment for standby operations and later retired existing equipment in favor of the gas-cutting equipment. This has proved that by taking time to get thoroughly acquainted with the process you will find an extremely adaptable and economic tool for many industrial problems.

Welding Highway Bridges

This article briefly describes some welded bridge structures either completed, under construction or soon to be advertised in Connecticut Highway System

by John F. Willis

WHILE each process of welding has its own particular application, the shielded-electric arc process is now generally conceded to be the most practical welding for structural assembly, either in shop or field. By this process it is usually possible for the operator to perform his work with one hand, leaving the other free for support. With gas welding this is seldom possible except when the work is in horizontal or flat position.

The best structural design of welded assembly always requires that as much shop welding be done as is possible, leaving minor details only to be done in the field. While this is not always practical it is usually possible to locate all field welds at points of zero or low stress.

In subsequent references, the structures in question are all on the Connecticut Highway System, either completed, under construction or soon to be advertised.

The idea of an all-welded bridge was conceived during the design period of the Merritt Parkway planning, and mostly because of one particularly ugly riveted rigid frame. Not only was the ugliness emphasized by the innumerable rivet heads but also by the prominence of what appeared to be unnecessarily large stiffener angles and awkward cover plates.

The desirability of maintaining the same general lines and at the same time eliminating the objectionable features left one answer—an all-welded structure.

The fact that there were several welded bridges in existence at that time was not well publicized. Knowledge of this would have greatly facilitated, if not promoted, this innovation. True to tradition, considerable opposition, reluctance and indifference prevented for some time authorization of a design, plans and contract for an all-welded bridge.

When the long-awaited consent was finally given, probably with fear and trepidation, plans for an all-welded steel rigid frame were produced. Now that it can be told, this design had been prepared, surreptitiously, in anticipation of its being finally accepted.

The usual being followed, a contract was awarded for what was termed by some who should have known better, as a "new fool idea." When, as is the usual custom, the shop plans were submitted by the fabricator for approval, the writer was astounded to observe that the said plans were for a completely riveted frame!

Without dwelling on the somewhat acrimonious discussion that followed, the fabricator was gently and firmly admonished that the design as planned by the state was the one deemed most desirable. It is needless to comment further on that particular project excepting to state that the bridge is still standing, despite the predictions of the antiwelding element.

After the original inertia had been overcome the path and progress became smoother. The state dropped all objection to welded structures and favorable comment from the public appeared. Nevertheless, the U. S.

John F. Willis is Engineer of Bridges and Structures, Connecticut Highway Department, Hartford, Conn.

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Public Roads Administration refused to sanction any welded structure or any on which welding was used for anything other than the assembly of minor details. This seemed inconsistent in view of the fact that the Navy had been making extensive use of welding for many years.

The Federal ban has now been lifted and any all-welded structure of good design will be accepted.

In bridge building, welded assembly has proved of particular value in I sections, that is, sections of the plate girder or rigid frame type.

Every all-welded bridge on the Connecticut Highway System is of either of the above types.

The old controversy of riveted vs. welded still continues and the proponents of each can undoubtedly prove, to their satisfaction at least, where lie economies and other desirable features.

One type of construction where welding is employed profitably is that known as "Composite." By this is meant that the concrete slab of the structure besides serving as a floor also functions as a compression flange, this of course, in simple beams or girders only. The composite action is accomplished by welding shear connectors to the top flange of the steel member and imbedding them in the slab when the concrete is poured. Spirally coiled rods with a pitch of the spirals established to conform to the design as determined from the horizontal shears make an excellent way of providing for the shear resistance between slab and steel member.

When the steel beams or girders can be supported in such a manner as to avoid all deflection when the concrete is poured, the composite section may be relied upon to resist both dead and live load moments. Where such support is impractical the composite action is considered as applying to the live and impact loads and any others which may be incurred after the concrete has hardened.

There seems to be little or no argument against the statement that a fully welded deck structure, lower flange reduced in area as the moment is reduced, upper flange designed as light as specifications will permit (the top flange is stressed very low in composite design), the structure supported during pouring and hardening of concrete, will yield as economical a structure as is possible to obtain. When it is not feasible to support the beams as mentioned, the composite action applies to live load stresses and the steel member must be designed to support the entire dead load. Even under these conditions, added to the fact that the composite action development is patented and royalties are required, the design is still economical.

At the present time it is practically impossible to make a really accurate cost analysis in comparing welded to riveted assembly, but a few facts concerning construction just prior to the war may establish definite conclusions as to the relative economies in welded construction.

The most outstanding example of economy in welded construction was accomplished in the design of the center suspended span of the bridge carrying the Hartford By-Pass over Jordan Lane and Wollcott Hill Road, known as "Jordan Lane Bridge." This element of the bridge is a simple span of 120-ft., 63-in. web and of the above-mentioned composite design. Full advantage of the composite effect was taken in account as was every advantage of welding. The estimated saving in structural steel was sufficient to yield a total saving in the cost of this span alone of over 30%, as compared to one of riveted design without provision for composite action. This statement has been questioned but the answer is obvious. A riveted girder of the above depth is far too shallow for any economy and necessitates unreasonable flange area as well as angle stiffeners which are at least 60% heavier than plate stiffeners as used in the welded design. When, as is the usual case with riveted girders, stiffener angles are used, fillers are necessary, thus again increasing the total weight. Even when the composite action is not figured, a stated flange area of welded design will require less metal than the equal in riveted because of the area deducted for rivet holes.

It is not intended to imply that the 30% saving in cost, above stated, was carried through the entire structure; this applied only to the suspended span. The total saving in the entire structure was about 14%. This is based on an estimated unit price of $0.06 for riveted work and $0.075 for welded. The latter price was that bid and the same as estimated The estimated price of $0.06 for the riveted design was the average of bids for this type at that time, 1940.

Extensive cost analyses of both riveted and welded designs have shown that the per pound cost of the latter has, in the past, exceeded that of the former but the saving in metal more than compensates for the higher unit cost.

At this writing the 1940 picture is no longer valid, at least as to the differential in unit prices of welding vs. riveting. As before stated, accurate cost analysis is difficult if not impossible. The trend is, however, to the good. Comparison between the two types in question reveal that welding unit bid prices are no longer above the riveted, they have been received equal to and even lower in some instances. All structural steel bids, of late, have been entirely out of line and unreasonably high. This is entirely chargeable to the fluctuation of steel and not to the method of assembly.

One of the very few encouraging effects of the war was that due to the tremendous amount of welding required to produce our ships and almost every other instrument of battle, transportation or food, a large harvest of capable and efficient welders was reaped. Probably under no other circumstances would we have trained so many skilled artisans in this highly specialized profession. When, and probably if, the normal production of steel is resumed there is reasonably good chance that welded assembly will cost less than riveted, per pound as well as the total.

It is readily understandable why there existed a reluctance on the part of steel fabricators to enthuse over welded assembly. They had a highly and expensively

trained staff of riveters as well as millions of dollars tied up in punching, drilling and riveting equipment. Furthermore, satisfactory automatic welding machines had not been developed nor was there much information available on welding costs. Welding research was in its infancy and first-class welding operators were few and far between.

These difficulties now being overcome it is only reasonable to assume that far more structural welding may be expected in the future than formerly.

There have, at this time, been designed 26 all welded structures of all types, that is, arches, rigid frames and girders, serving as railroad and highway grade separations, stream crossings and the combination of both or all.

Of these 17 are completed and in use, 6 are under construction and the remaining 3 are either designed and awaiting advertising or are in the process of design. Planning for the immediate future includes many more.

Of the above structures classed as all-welded, it should be understood that only structures completely assembled by this process are so classed. Where welding has been used for attaching sole or cover plates, diaphragms or minor nonstress carrying details to rolled beams, these bridges are not known as "all-welded."

Periodic inspection of the welded structures now in use, some nearly 10 years old, has revealed no defects such as warping or cracking. In one case, however, a two-span continuous rigid frame, a few radial cracks in the structure appeared. Six or seven years have elapsed since this discovery and no further deterioration is visible.

Over the period of the years since the first welded bridges were built in Connecticut, there has been a wide range of temperature variation. Moreover, both the design and the workmanship were inferior eight years ago to what they are now. These, and many other facts all add up to form the conclusion that it is sound practice and is both economically and architecturally advantageous.

As to the predictions of the future of welding one can be well reminded of an answer given by Mark Twain when his opinion was asked about the weather, "I think it is here to stay."

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(*Continued on page 238*)

Inert-Gas-Shielded-Arc Welding Equipment

This article traces the evolutionary design changes in the various parts of the equipment needed for modern shielded arc welding

by N. E. Anderson

THE process of electric arc welding in an inert-gas atmosphere is finding ever-increasing application especially for the fabrication of those metals hitherto considered "hard-to-weld." These materials, largely, have required the use of bothersome fluxes, which in turn require time consuming, often difficult, clean-up measures for the sake of appearance, sanitation or prevention of postweld corrosion. Aluminum, magnesium, stainless steels, brasses, copper, etc., fall in this category. Furthermore, the inert-gas-shielded arc provides heat input characteristics which suit the process for even extremely thin materials, which can be welded with little or no distortion.

The fundamental feature of the process is the shrouding of the electrode, the concentrated arc and the molten area of the work by a sheath of inert gas, issuing from a nozzle at low velocity to form a protective blanket. Thus the electrode and molten metal are protected from oxidation, and with the help of electrical factors, which can be used to break up preweld oxide films, the entire problem of fluxes for the highly oxidizable metals is solved.

Economic factors delayed the use of the process, which was originally developed nearly 20 years ago, until the need for a satisfactory welding method for magnesium arose about 1939. Brought to attention by its success on magnesium, inert-gas-shielded arc welding was soon applied with gratifying results to other materials, and the process has grown steadily and rapidly to a position of key importance today. The most vigorous development work was required to evolve equipment to keep pace with the demand for the process in an ever widening field of application. While the fundamental function of any inert-gas-shielded arc welding apparatus must be the same, the quality and quantity requirement for use of the process as a mass production tool have made it necessary to surround this central function with numerous refinements and auxiliary functions, so that a modern installation, if the job requires it, may be a rather elaborate arrangement. Less demanding production requirements, however, may be more elementary, since the basic equipment for the process is simple.

The fundamental element of any apparatus for the application of the process is the electrode holder, and its original characteristic functions, which were provided in the most rudimentary holders, remain unchanged:

To provide electrical conductivity to the electrode.
To direct the shielding gas to provide an adequate sheath around the electrode and the weld pool.
To provide for necessary positioning and maneuvering of the electrode in relation to the joint.

These rather simple requirements were met easily enough in the original development of the basic process. It was a long way, however, from an electrode holder that "worked" to a reliable mass-production tool.

The first production electrode holders (Fig.1) were designed for manual operation, welding magnesium with reversed polarity direct current up to about 125 amp. They were satisfactory in lightness, handling ease and maneuverability, but their working range was sharply limited. Particularly in using reversed polarity cur-

Fig. 1 An early production model noncooled manual electrode holder for inert-gas-shielded arc welding

N. E. Anderson is with the Apparatus Department of the Air Reduction Laboratories, Murray Hill, N. J.

Not presented at A.W.S. Annual Meeting

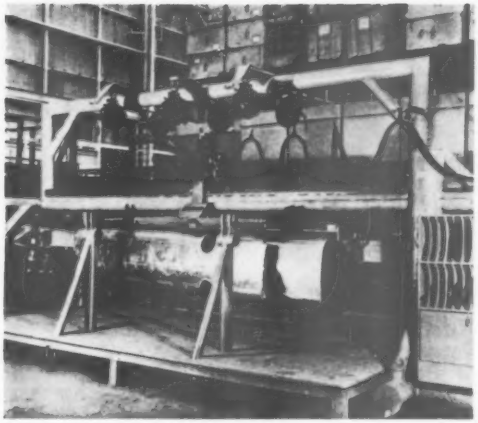

Fig. 2 Jig and welding setup for longitudinal seams of aircraft wing-tanks, machine-welded with a noncooled manual holder (Fig. 1) carried on a radiagraph

rent, the problem of heat in the holder was a major obstacle to use of such a noncooled design as a production tool. While some improvements in design and capacity were achieved, it was not until water-cooled equipment was developed that the process could be fully used.

The war, however, blocked such developments for a few years, and at the same time, spurred the demand for the process, which was of great value in aircraft production. To turn out the thousands of units required, aircraft producers attempted to mechanize the process, and obtain some degree of automatic operation, even with the low-capacity holders available (Fig. 2). When such stop-gap arrangements proved capable of production work, even within their sharp limitations, the basis was established for the development of truly mechanized and automatic equipment as soon as conditions permitted.

Fig. 3 Except for an experimental air-cooled manual holder (lower left) the units pictured are various preliminary designs for heavy-duty water-cooled machine-type electrode holders

This development took two lines, related, but with somewhat different objectives. One was the development of a holder suitable for continuous duty at relatively high currents, mountable for repetitive operations on straight line or rotating work. The other was a fully automatic, self-adjusting unit which could produce quality welds on varying contours on a continuous mass-production basis. Starting from the basic requirements cited above, investigation of the arc, gas shield and welding characteristics was undertaken* to

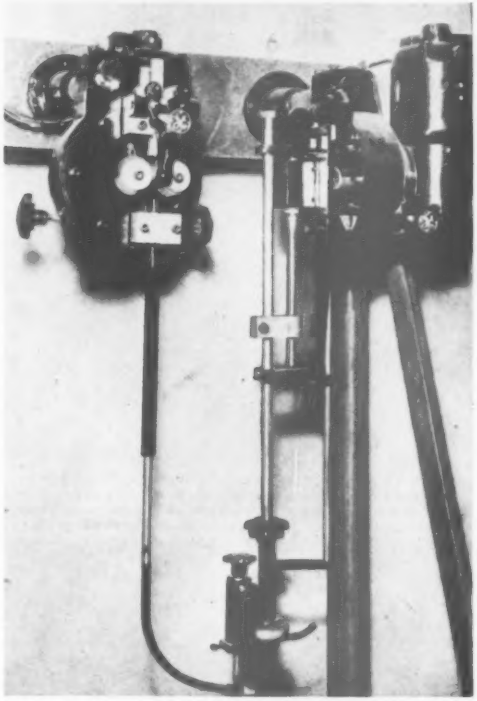

Fig. 4 One of the earliest working models of an automatic unit for inert-gas-shielded arc welding. A filler wire feeder is at left, welding unit proper at the right

determine fully the requirements of satisfactory equipment for these purposes. In the course of this and other development work, a variety of experimental machine-type electrode holders (Fig. 3) were developed, tried and discarded, until a unit of satisfactory performance and durability was evolved. At the same time, a suitable mechanism for automatic welding was being developed (Fig. 4), the final design being one in which the same electrode holder could be mounted, and heavy duty water-cooled manual equipment was evolved.

In the development of these units, the basic functions were expanded somewhat over the rudimentary essentials, to:

* Gibson, G. J., "The Inert-Gas-Shielded Arc-Welding Process," THE WELDING JOURNAL, **26** (5), Research Suppl., 282-s to 294-s (1947).

Fig. 5

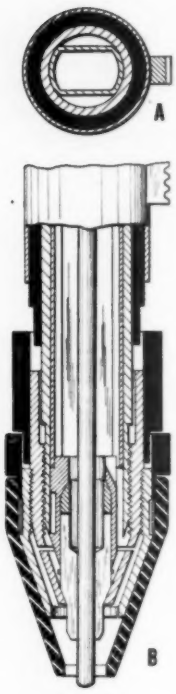

Fig. 6

Fig. 5 Final design of machine type electrode holder has little resemblance to the earlier attempts shown in Fig. 3. Fig. 6 (A) Horizontal cross-section, lower end of machine electrode holder. (B) Vertical section, note that the black areas of insulation overlap completely from the ceramic gas nozzle (heavy black bars) to the enclosed over-all barrel insulation at top

1. Provide electrical and thermal conductivity from the welding cable and cooling medium to the electrode gripping device.
2. Provide means for easy adjustment of electrode protrusion, yet grip the electrode securely for mechanical support as well as electrical and thermal conductivity.
3. Direct the shielding gas to provide a protective sheath around the electrode and over the molten weld metal.
4. Provide storage space for unused electrode length.
5. Provide adequate strength and insulation for heavy duty high-current operation without undue weight or bulk.

The simplest illustration of the features which meet these requirements is the machine type electrode holder, Fig. 5. This holder is used for both mechanized and automatic applications, and the water-cooled manual equipment is basically the same although reduced in size and weight to permit easier manual handling.

The threaded portion protruding from the top of the machine holder is a combination stud and gas fitting. It is threaded, bored and countersunk to accommodate a standard hose gland and gland nut at its extremity, and the gland nut threads are extended to form a stud that provides the connection to the welding cable lug. The jam nut for securing the cable lug is of the same thread size as the gland nut. The hose connection nipples protruding from the right side are for cooling water supply and discharge.

Figure 6 (*A*) is a horizontal cross section of the holder barrel. The center member of the barrel has two flat sides and two arcuate sides. This serves as the inert-gas conduit as well as storage space for unused electrode lengths up to 18 in. The metal cylinder surrounding the center member is the main electrical conductor. The two spaces between the inside of this cylinder and the two flat sides of the center member form two separate passages to conduct cooling water to and from the electrode gripping device. Surrounding the current conducting cylinder is a cylinder of insulating material, and this is all contained within the outer metal tube to which is attached a gear rack for raising and lowering the unit when it is installed in a standard oxyacetylene torch holder equipped with adjusting wheel and pinion. Figure 6 (*B*) is a vertical section of the lower end of the holder showing the electrode in place, electrode gripping collet (interchangeable for various electrode diameters), and the insulated compression nut for compressing the collet fingers into gripping engagement upon the electrode, and for pressing the collet against a water-cooled seat.

The outer cylindrical surface of the compression nut is threaded for a cylindro-conical bushing that carries the gas nozzle, which is held in place by a resilient retaining ring. The nozzle bushing may be run down on its threads for a short distance and the electrode adjusted for proper protrusion at the beginning of a shift of a long continuous weld. To maintain proper electrode protrusion as the electrode slowly vaporizes the bushing may be screwed back up on its threads, instead of interrupting the welding operation to adjust the electrode in the collet. All current carrying parts are insulated, and a rubber hood covers and insulates the the exposed connections at the top of the holder.

However much an electrode holder of any manufacture, shape or size may vary, it must perform the functions outlined above, and can differ only in assembly details from the holder described.

To cool the electrode properly for maximum capacity with a given size of electrode; to minimize radiation of heat from the electrode to the gas nozzle and to cut down on the length of unusable electrode stubs, there should be a minimum of electrode length outside the collet. The proximity of the collet to the nozzle orifice is not altogether compatible with the desirable smooth gas flow for optimum gas coverage, and any design must necessarily compromise somewhat between these two requirements.

Air-cooled holders have no water passages, but depend for cooling upon heat conduction back through the welding cable and upon radiation into the atmosphere.

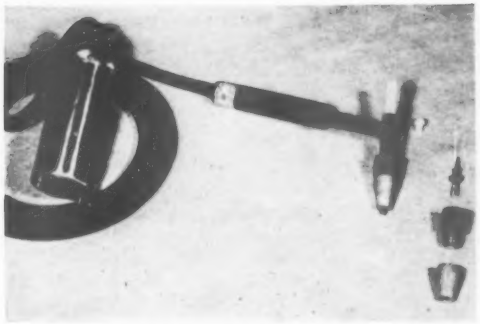

Fig. 7 Manual water-cooled electrode holder of high current capacity retains desirable lightness and maneuverability, with single light flexible lead, ending in connection assembly, carrying gas, water and current to the holder itself

Many types of holders do not allow adjustment of electrode protrusion without interruption of the welding cycle.

Some types can be furnished with water-cooled metal gas nozzles. However, accidental contact of a metal nozzle with the work may cause the arc to transfer to and melt the nozzle, and for manual operation where such accidents may be frequent, ceramic nozzles are more desirable. Ceramic nozzles are available which are quite resistant to thermal and mechanical shock, and will give satisfactory service in the current range used for the majority of manual operations.

A typical manual water-cooled holder is shown in Fig. 7. Standard welding cable and gas and water hoses terminate in the bullet shaped connector assembly, where the various utilities are transferred to pass within a single, very flexible cable to the handle of the holder proper. Except for shape and size, the holder proper is practically identical with the machine electrode holder previously described. Being designed for manual operation, however, it is light and relatively compact, and with the light, flexible single cable provides excellent maneuverability with minimum operator fatigue. For work in close quarters, the extension shown in Fig. 7, which is designed to accommodate the more economical longer electrode lengths, may be removed and replaced with a flush cap.

The single cable between the connector assembly and the manual holder is usually provided, for routine manual work, in a 10-ft. length, and is integral with the holder itself. For special requirements, however, it may be made as long as 25-ft. without impairing its operating efficiency. The cable consists of a light plastic outer tubing enclosing a pair of flexible braided current conductors and hoses for shielding gas and the ingoing cooling water. Outgoing cooling water flows through the outer cover, serving to cool and thus increase the current capacity of the braided conductors. While the advantages of lightness and flexibility of such a cable assembly are valuable, there is a natural limit on the length which can be efficiently used. It would be a most exceptional case, however, which would require more than the recommended 25-ft. maximum length.

While the manual holder is designed only for positioning and maneuvering by the operator, the machine

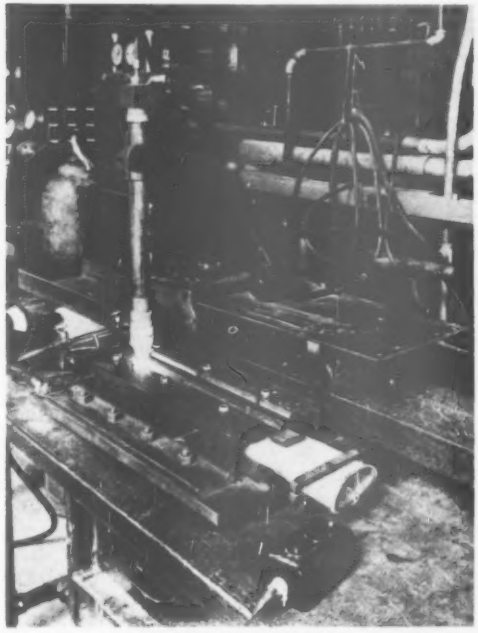

Fig. 8 Machine type electrode holder, mounted with standard cutting torch fittings, on a radiagraph which serves as travel carriage

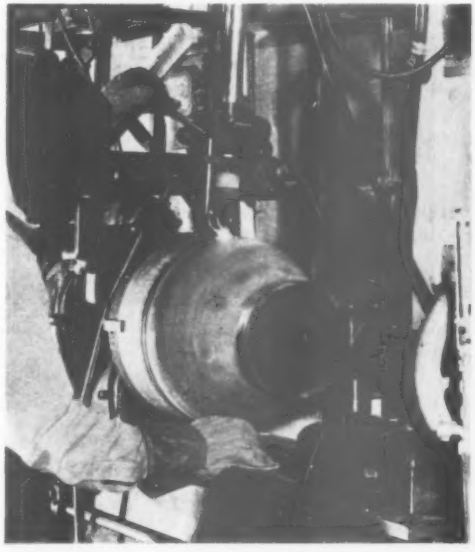

Fig. 9 Machine type electrode holder mounted on a fixed bracket provided with means of adjusting arc length and electrode position, while the part to be welded rotates under the arc

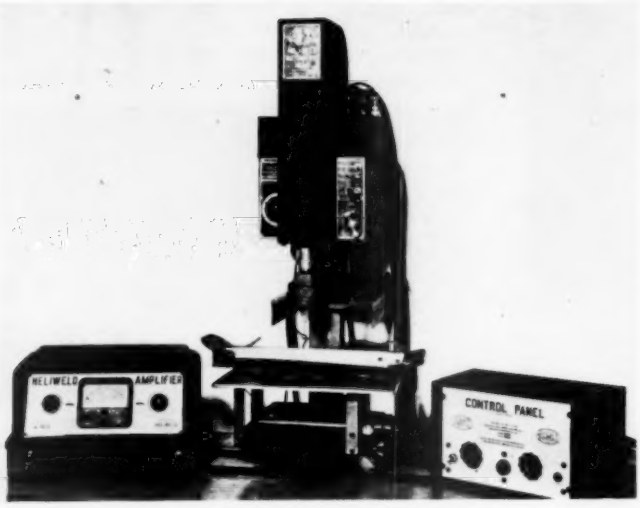

Fig. 10 Automatic welding head. Central unit holds machine-type electrode holder, drive motors and positioning controls. Amplifier circuits (left unit) control arc-length reaction to arc-voltage changes. Workpiece is here carried on a modified radiagraph. In other application, the automatic head itself could be mounted to travel over the seam

holder is designed for a fixed mount, either on its own travel mechanism (Fig. 8) or with a travel mechanism for the workpiece (Fig. 9). In either case, the workpiece is held firmly in position by a jig, and arc length and centering adjustments are provided in the mounting of the holder, either by a universal positioning device such as that in Fig. 8, or by rack adjustments as in Fig. 9. The arc length adjustment is necessary for consistant penetration and quality welds.

The characteristic of the arc and of welding generators in general is such that with constant welding speed and constant arc length, uniform heat can be obtained resulting in consistent penetration and bead form. On flat butt joints and on girth welds that can be well jigged and securely clamped to prevent warping, the setups shown in Figs. 8 and 9, with manual adjustment of arc length as required, will usually produce satisfactory welds. Since arc voltage is a function of arc length, a voltmeter measuring arc voltage will indicate the proper arc-length setting.

With any arrangement depending upon manual adjustments, quite close operator supervision is necessary to adjust for variations in the joint surface and for erosion of the electrode, and appreciable skill may be required to make smooth precise compensations. Furthermore, there are many contour welding applications and many types of joint which cannot be firmly jigged to prevent warping. Even in welding metal tubing seams, the final forming rolls may allow up to 0.010 in. of vertical motion of the seam, and this amount of change in arc length in many instances has been found too great to produce uniformly sound welds with a fixed electrode holder. From such factors, it is apparent that a means of automatically controlling arc length is not only desirable, but for many purposes, essential. With this central function as the core, a production type automatic head for inert-gas-shielded arc welding was developed (Fig. 10).

With the arc in an inert-gas shield, the slope of the arc-voltage versus arc-length characteristic is very flat, and considering the fact that positioning is the most difficult of servo-mechanism applications, an electronic amplifier is needed to control the motors that position a machine electrode holder in the automatic head. The unit also includes a self-contained automatic touch starter for striking the arc, with micrometer adjustment of electrode withdrawal to assure proper initial arc length. Means are provided for automatic starting of a travel carriage coincidental with the striking of the arc, and withdrawal of the electrode holder at the termination of the weld is automatic and can be adjusted in amount so as to clear the welding jig. For double-jig operation, the head may be rotated 340° around its post, and has adjustable stops for the two positions with micrometer adjustment in each position for centering the electrode over the seam. The head may be used with either helium or argon, for a.-c. or d.-c. operation.

The automatic adjustment of arc length to a preset arc voltage constant, which is the central feature of the automatic head, not only permits automatic adjustment for irregularities in an otherwise regular joint contour, flat or round, and for electrode erosion, but it

Fig. 11 This stainless steel bedpan is ideally suited in contour for automatic heliwelding. Curves of constantly changing radii, thin material, sanitary requirement of a highly smooth bead are all handled by the electronically controlled equipment and good jigging

permits automatic welding of irregular contours, such as both a curve of varying radius and a change to a straight section at one end, or oval, elliptical parabolic, and compound contours, such as that of Fig. 11 within the limits of the travel speed—electrode speed ratio of the head.

AUXILIARY EQUIPMENT

In addition to the well- known standard d.-c. and a.-c. welding machines, gas flow regulators and gas flow meters, there are several special auxiliary equipments that may be desirable or necessary depending upon the type of metal to be welded or upon the degree of convenience desired in the operation.

When using alternating current, as on aluminum and magnesium, it is necessary to provide a means of stabilizing the arc. A spark gas oscillator is one means of obtaining this arc stabilization, and also eliminates the need for touch starting in any type of welding. Such oscillators, however, are restricted in use because of radio band interference, and more recent practice is to use them if at all, only for arc starting, with a high open-circuit voltage serving to stabilize the a.-c. arc. When the oscillator is used, its function is to provide an ionized path for reignition of the arc during current reversal with a. c., and to ionize the arc gap, if voltage amplitude is sufficient, so that a welding arc may be initiated without touching the electrode to the work.

Other auxiliary devices of more or less fundamental importance include means of protecting apparatus against cooling water failure, means of filtering cooling water, and at-the-work control of gas and water flows and welding current. With such controls, it is usually highly desirable to have them centralized.

When it is desired to eliminate the phenomonen described as "d.-c. component"* from a.-c. welding current, storage batteries or capacitors may be used in series with the welding transformer. Approximately 100 mfd. of capacitor is necessary per ampere of welding current.

Figure 12 is a complete balanced a.-c. power source and control unit, including all the facilities for a.-c. welding with the inert-gas-shielded arc process. It features a built-in contactor; water interlock; solenoid operated gas and water valves; series capacitors; high frequency for arc starting; 100–150-volt secondary; and a 25–35-volt pilot voltage for use in manual welding. Safety interlocks make it impossible to have full open-circuit secondary voltage at the electrode for more than $\frac{1}{2}$ sec. if the arc fails to strike This unit can be furnished with an automatic crater filler if desired.

Other items which may be used are foot operated switches, separate water flow interlocks, an automatic touch starter and positioner for machine type holders and a filler rod feeder for use with the machine type

Fig. 12 A complete balanced a.-c. power source and control unit for a.-c. inert-gas-shielded arc welding with all necessary auxiliary control and safety measures built in

holder in either fully automatic or mechanized installations. In d.-c. welding, to prevent wandering of the arc at low currents and to prevent arc-blow at high currents, magnetic stabilization of the arc may be necessary, and a magnetic gas nozzle can be used for this purpose in place of the usual ceramic part.

INSTALLATIONS

Since this is a relatively new welding process, and the equipment for it has been developed in a comparatively short span of time, a great deal of uncertainty exists in the minds of the prospective user as to what constitutes a complete and efficient installation for various types of work. To help clarify this situation, a series of diagrams have been prepared to show typical installations for basic sets of conditions. Minor variations from these are possible, of course, but they are sufficiently standardized to serve as a practical guide.

Figures 13–16 illustrate various hook-ups for either the water-cooled manual electrode holder or the machine type electrode holder, which are interchangeable as far as auxiliary equipment is concerned, except for such equipment as is used to position the machine holder.

While Fig. 13 does not represent the very simplest possible setup for welding, it does include the minimum recommended equipment for efficient and safe production work. For an absolute minimum installation, the

* Gibson, G. V., and Rothschild, G. R., "The Effect of D.-C. Component in A.-C. Inert-Gas-Shielded Arc Welding." Presented at the Annual Meeting of A.W.S. on Oct. 27, 1948.

filter, water interlock and gas saver could be omitted (as they are in the a.-c. setup of Fig. 15), but such rudimentary arrangements will not usually prove very satisfactory for continuous work. This setup, when used with a machine holder, would substitute an at-the-work gas shut off valve for the gas saver.

In Fig. 14, the various basic auxiliaries are grouped in a single control panel unit, which also provides for a foot (or other type) switch to open and close the welding current. In this d.-c. setup, the entire operation can be controlled at the work with what amounts to "push-button" operation.

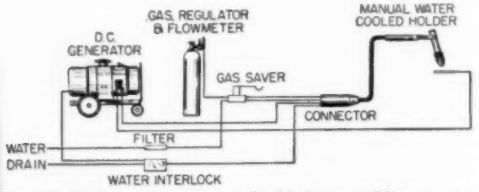

Fig 13 Layout of inert-gas-shielded arc welding equipment for manual or machine work using separate auxiliary devices, d.-c. welding

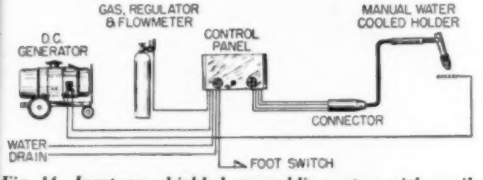

Fig. 14 Inert-gas-shielded arc welding setup with auxiliary devices and controls packaged in a centralized control panel, suitable for manual operation (as shown) or machine work, with d.-c.

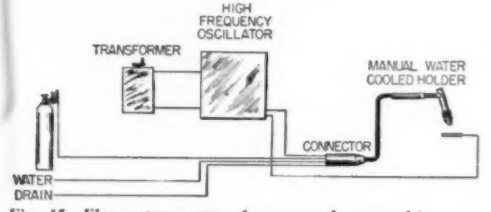

Fig. 15 Elementary setup for manual or machine a.-c. welding with a standard a.-c. transformer and high frequency for arc stability. No auxiliary protective or control measures included

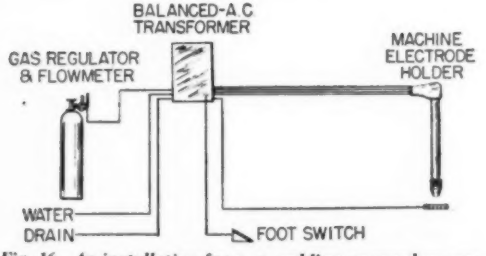

Fig. 16 An installation for a.-c. welding, manual or machine holder, with a "package" transformer unit incorporating control and protective devices with the welding current source

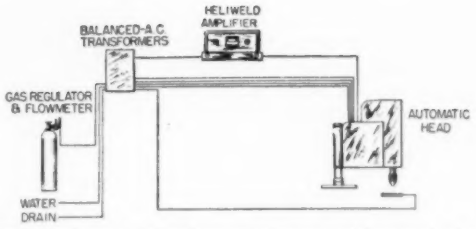

Fig. 17 Layout of equipment for a.-c. welding with the automatic head

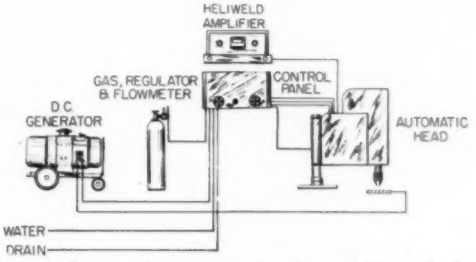

Fig. 18 Layout of equipment for d.-c. welding with the automatic head

Figure 15 illustrates the arrangements for the simplest type of a.-c. installation using a high-frequency oscillator for arc stability. To provide the auxiliary measures shown for d. c. work in Figs. 13 and 14, the two units comprising the a.-c. power source are substituted for the d.-c. generator shown in these diagrams.

Figure 16 shows the arrangement of a completely outfitted a.-c. welding installation using the balanced a.-c. transformer which incorporates all the auxiliary controls and devices in one package (Fig. 12). One of the chief advantages of such a current source unit is readily apparent from the greatly increased simplicity of the layout as compared with Figs. 13–15.

In Fig. 17, the setup for a.-c. welding with the automatic head is illustrated. The additional element here is the amplifier which serves to increase the signal developed by the arc-length–arc-voltage changes and activate the servo mechanisms of the head. The package unit a.-c. transformer shown in Fig. 12 supplies the auxiliary measures required for the operation—water filter, interlock, momentary high frequency for arc starting, high open-circuit voltage for arc stability, etc.—and at-the-work control of the operation is provided in the head itself.

For d.-c. welding with the automatic head, Fig. 18, the control panel unit fulfills the functions provided in the transformer package shown in Fig. 17, so that except for the amplifier, this installation contains much the same auxiliary elements as a d.-c. setup for manual or machine holder work.

Variations on these circuits can be readily worked out for special jobs and differing requirements. Up to date inert-gas-shielded arc welding equipment has definitely become a group of mass-production tools of satisfactory versatility, precision and capacity.

The Definition of Welding Positions

This article describes how and why the proposals made by the British Joint Committee, in connection with definitions of welding positions, differ from the American and Australian proposals and indicates the necessity for an endeavor to obtain uniformity

by E. Flintham, M. Inst. W.

INTRODUCTORY SUMMARY

Since the publication of the British Electrode Classification,[1] which was prepared by a Joint Committee representative of manufacturers and users appointed by the Arc Welding Electrode Section of The British Electrical and Allied Manufacturers' Association (Inc.), and by the Institute of Welding, there has been some criticism of the manner in which this Joint Committee dealt with the definition of welding positions.

Recently, the Australian Welding Institute Inc., Sydney, has published a proposed specification[2] defining welding positions. The American,[3] the Australian and the recent British Classifications have put forward different solutions of the problem of defining welding positions. This article describes how and why the proposals made by the British Joint Committee differ from the American and Australian proposals, and indicates the necessity for an endeavor to obtain uniformity.

GENERAL REQUIREMENTS

A classification of electrodes cannot be accepted as satisfactory unless it has taken into account the suitability of the electrodes for welding in various positions. Furthermore, no definitions of these various positions can be accepted as satisfactory unless the definitions are so precise that every person using them can classify, without doubt, any weld as being in a certain welding position. That is why simple definitions, such as those suggested by W. D. Waller[4] are not satisfactory for a system of classification.

The definition of welding positions was the problem which caused the most difficulty to the Joint Committee. At first sight such definitions seem quite easy to make but there are many traps for the unwary. For example, in the first classification issued in 1944 by B.E.A.M.A.[5] the weld commonly referred to in Britain as a "standing fillet" complied with the definition for a "semi-inclined" weld! The definitions must cover welds in all possible positions and the temptation to overlap the definitions of the various positions must be avoided. Moreover, the definitions must take into account the welding technique required to deposit metal in the position defined and, if possible, be compatible with accepted workshop usage in such matters as demarcations adopted for piecework rates, etc.

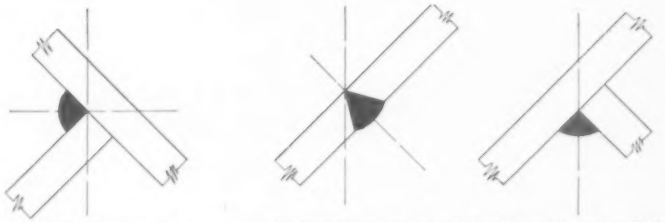

Fig. 1 Typical angles of rotation as defined by the three classifications

POSITION OF THE NORMAL OF THE WELD

It has to be borne in mind that the normal of a weld may be in the vertical plane or may be at an angle to that plane. Similarly, the linear axis of the weld may be in the horizontal plane or may be at an angle to that plane. Therefore, in order to define the position of a weld, it is necessary to take account of the angle the normal of the weld bears to the vertical plane and of the angle the linear axis of the weld bears to the horizontal plane.

In all three classifications the angle that the normal of the weld bears to the vertical plane is termed the "rotation of the weld." In the British and Australian classifications the angle is determined from the upper portion of the vertical reference plane and measured in either a clockwise or anticlockwise direction to a maximum of 180° rotation. In the American classification the angle is determined from the lower portion of the vertical reference plane and measured in a clockwise direction to a maximum of 360° rotation. Figure 1 shows typical angles of rotation defined in accordance with the three classifications.

In the author's opinion, the British and Australian method of defining the weld rotation in either direction from the vertical plane is the better method. Furthermore, it is easier to imagine a butt weld in the true gravity welding position as having 0° rotation whereas in the American method this weld is defined as having 180° rotation.

POSITION OF THE LINEAR AXIS OF THE WELD

In the British and Australian classifications the angle that the linear axis bears to the horizontal plane is termed the "slope of the weld." In the American classification this angle is termed the "inclination of the axis." In all three classifications the horizontal plane of reference is below the weld under consideration and for practical purposes the angle of the weld to the ground level determines the slope or inclination.

DEFINITION OF WELDING POSITIONS

By defining the terms "Weld Rotation" and "Weld Slope," means are provided by which it is possible to establish the position of a weld by angular measurements from

E. Flintham is Chief Chemist with The Quasi-Arc Company, Ltd., Bilston, England.

defined vertical and horizontal planes of reference. Therefore, all that is necessary for the definition of welding positions is to decide how many different welding positions shall be classified and to state the angular measurements of rotation and slope which mark acceptable boundaries for the different positions.

The normal of the weld commonly known in Britain as a "standing fillet," has a rotation of 45° when compared with the normal of a butt weld in the true gravity welding position. Furthermore, the angle between the fusion faces of a fillet weld is usually 90° whereas the angle between the fusion faces of a butt weld is usually 60°. These two facts make it necessary to consider whether the welding positions for butt welds should be defined separately from those for fillet welds. The American classification does define them separately; the British and Australian classifications include both butt and fillet welds in each definition.

The American classification specifies Flat, Horizontal, Overhead and two subdivisions of Vertical welding positions and the definitions for groove and fillet welds differ, except in the Flat and the true Vertical positions.

The Australian classification specifies the following welding positions: Flat Downhand, Oblique Downhand, Horizontal, Oblique Overhead, Flat Overhead, Vertical and Semivertical.

It was decided by the Joint Committee preparing the British Classification that all welds could be classified as being in the Flat, Inclined, Horizontal-vertical, Vertical or Overhead welding positions but it was only after much discussion and many practical tests that the boundaries for these positions were agreed.

ANGLE OF SLOPE

Dealing first with the angle of slope, the Joint Committee decided to divide the possible slope between 0 and 90° into three divisions: 0 to 10°; 10 to 45°; and 45 to 90°. These divisions do not agree with the American classification which stipulates 0 to 15°; 15 to 80°; and 80 to 90°; nor with the Australian classification which stipulates 0 to 15°; 15 to 75°; and 75 to 90°. The welding of a joint sloped at an angle greater than 10°, i.e., at a gradient greater than 2 in. per foot run of weld, may be difficult with an electrode producing a very fluid slag and designed for welding in the flat position only. The Committee was guided to fix the other demarcation line at 45° principally because:

(*a*) This angle does not conflict with existing British Standard definitions.

(*b*) It is customary to use the vertical welding technique for welds made in a surface lying at an angle less than 45° to the vertical.

(*c*) By common workshop usage the angle of 45° is accepted as a demarcation line for vertical welds, e.g., for piecework rates.

ANGLE OF ROTATION

The Joint Committee decided to designate the possible rotation as from 0 to 180° in either a clockwise or anticlockwise direction and to divide into three divisions: 0 to 10°, 10 to 90° and 90 to 180°. These divisions do not agree with the Australian classification which stipulates 0 to 20°, 20 to 70°, 70 to 110°, 110 to 155° and 155 to 180°. As mentioned before, the American classification measures the angle of rotation from the lower portion of the vertical reference plane and from 0 to 360°. Converting the American stipulations to terms as used by the other classifications, the divisions are 0 to 30°, 30 to 100° and 100 to 180° for groove welds and 0 to 30°, 30 to 55° and 55 to 180° for fillet welds.

In fixing these divisions, the Joint Committee had in mind the necessity for simplicity and it is doubtful whether the more complicated divisions specified by the other classifications are justified, because on test they will be found to be inconsistent with the welding techniques required.

COMPARISON OF DEFINITIONS OF WELDING POSITIONS

To enable a ready comparison of the various definitions to be made, the American classification stipulations for angle of rotation have been converted to quote ro-

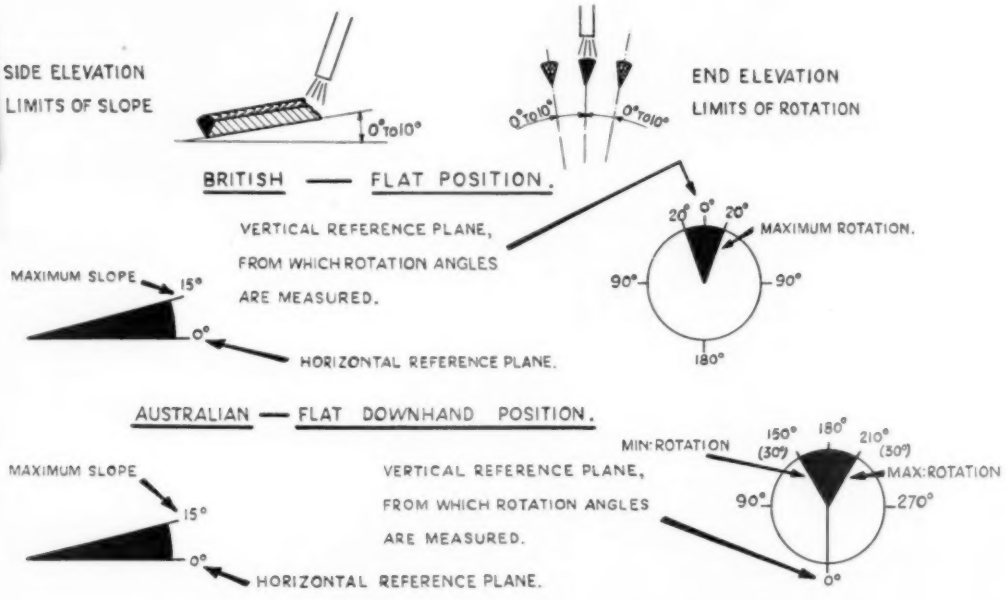

Fig. 2 Comparison of Group 1 welding positions

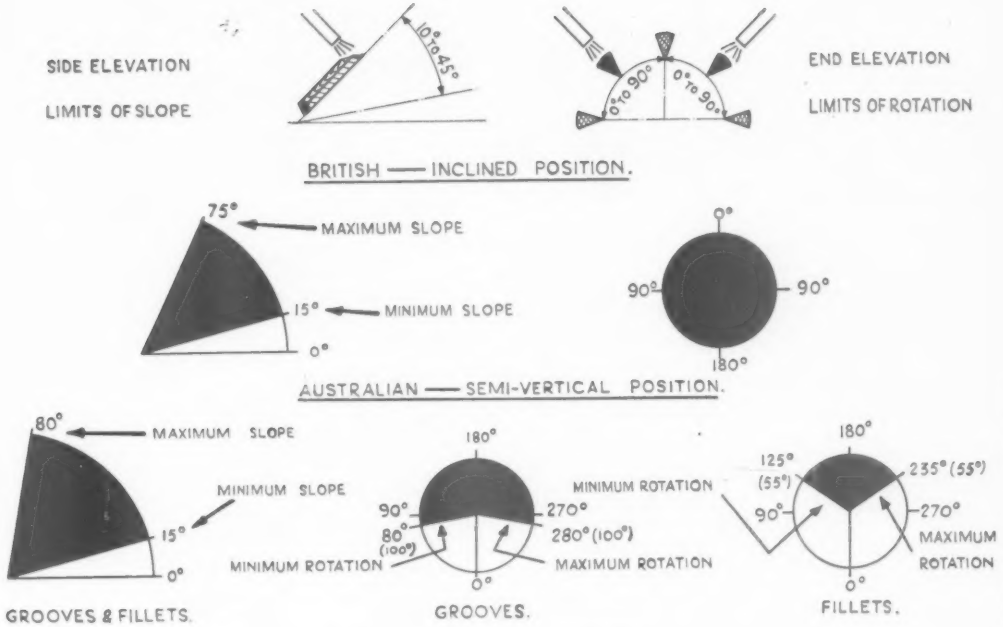

Fig. 3 Comparison of Group 2 welding positions

tations from the same zero as that used for the British and Australian classifications.

Group 1 (Fig. 2)

Flat (British and American); Flat Downhand (Australian).

	British	*Australian*	*American*
Slope	0 to 10°	0 to	15°
Rotation	0 to 10°	0 to 2	30°

The 15° slope permitted by the American and Australian classifications is equivalent to a gradient of 3 in. per foot run of weld and this seems to be far too great a gradient to accept as a flat weld. Using certain electrodes giving a fluid slag, but satisfactory for use at or near gravity welding positions, it would be almost impossible to obtain a satisfactory weld in a position having 15° slope and 30° rotation. Welding tests confirm that the British classification permits the maximum variations from the true gravity position within which it would be reasonable to expect to obtain satisfactory results, irrespective of whether the welding is done up or down the gradient, when using an electrode approved for the *flat position only*.

Group 2 (Fig. 3)

Inclined (British); Semivertical (Australian); Vertical D. for groove welds and Vertical D. for fillet welds (American).

	British	*Australian*	*American*
Slope	10 to 45°	15 to 75°	15 to 80°
Rotation	0 to 90°	0 to 180°	Grooves 0 to 100° Fillets 0 to 55°

The most surprising definition in this group is that given by the Australian classification. It is difficult to imagine how a weld having a rotation in the vicinity of 180° and with a slope of less than 45° could be classed as anything other than as an overhead weld. Similarly, it is difficult to understand why the American classification does not class a weld as vertical when it has a slope in the vicinity of 80° irrespective of the amount of rotation. It will be seen that, except in the case of fillet welds, the British classification of Inclined position is narrower than the

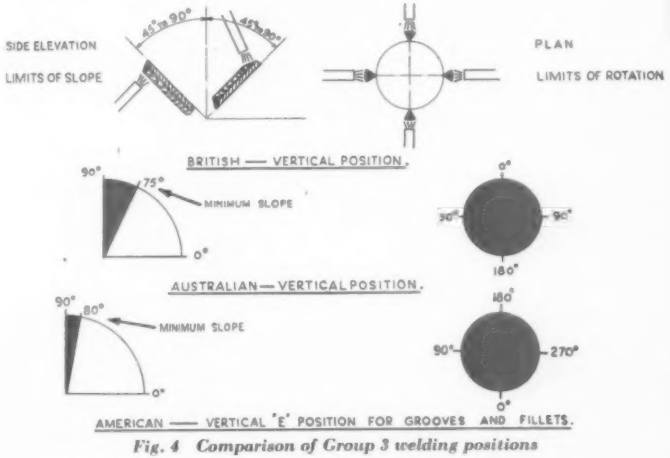

Fig. 4 Comparison of Group 3 welding positions

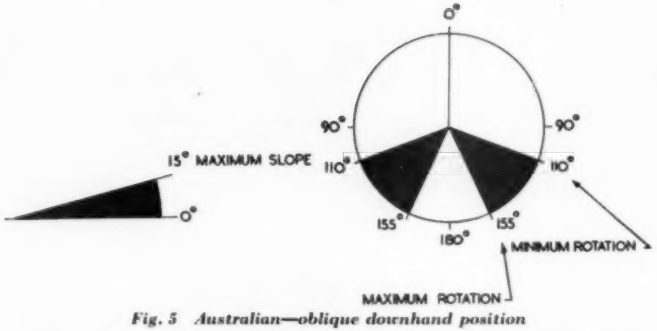

Fig. 5 Australian—oblique downhand position

Australian and American classifications in this group. The Joint Committee recognized that welds having a slope exceeding 10°, but not more than 45°, and having a rotation not exceeding 90°, lie within what is probably the most difficult welding position and therefore decided that there was a need for a special classification of such welds and the designation of "Inclined Position" is an appropriate description for them.

Group 3 (Fig. 4)

Vertical (British and Australian); Vertical E. for groove welds and Vertical E. for fillet welds (American)

	British	*Australian*	*American*
Slope	45 to 90°	75 to 90°	80 to 90°
Rotation	0 to 180°	0 to 180°	0 to 180°

When the weld has a slope of 80° or more, all three classifications designate them as vertical welds. Welding tests confirm that the vertical welding technique is required for welds having a slope greater than 45° and therefore the British classification of vertical welds includes welds that are variously classed as Semi-vertical, Vertical and Overhead by the other two classifications.

Group 4 (Fig. 5)

Oblique Downhand	*(Australian)*
Slope	0 to 15°
Rotation	20 to 70°

This Australian definition covers welds which are included mainly in the Horizontal-vertical position and partly in the Inclined position of the British classification. In the American classification, these welds are included mainly in the Horizontal position, partly in the Flat position and partly in the Overhead position! Add to this confusion, the fact that the weld commonly known as a "standing fillet" is designated by the Australian classification as an Oblique Downhand weld, it then becomes apparent that this definition is peculiarly inappropriate.

Group 5 (Fig. 6)

Horizontal-vertical (British); Horizontal (Australian); Horizontal for groove welds and Horizontal for fillet welds (American).

	British	*Australian*
Slope	0 to 10°	0 to 15°
Rotation	10 to 90°	70 to 110°

	American
Slope	0 to 15°
Rotation	Grooves 30 to 100°
	Fillets 30 to 55°

The definition in the British classification covers a greater rotation than that allowed by the other classifications but this is compensated by the lower maximum slope permitted. The range of rotation for fillet welds in the American classification seems to be unnecessarily restricted and it will be noticed that the maximum rotation permitted is lower than the minimum rotation fixed by the Australian classification.

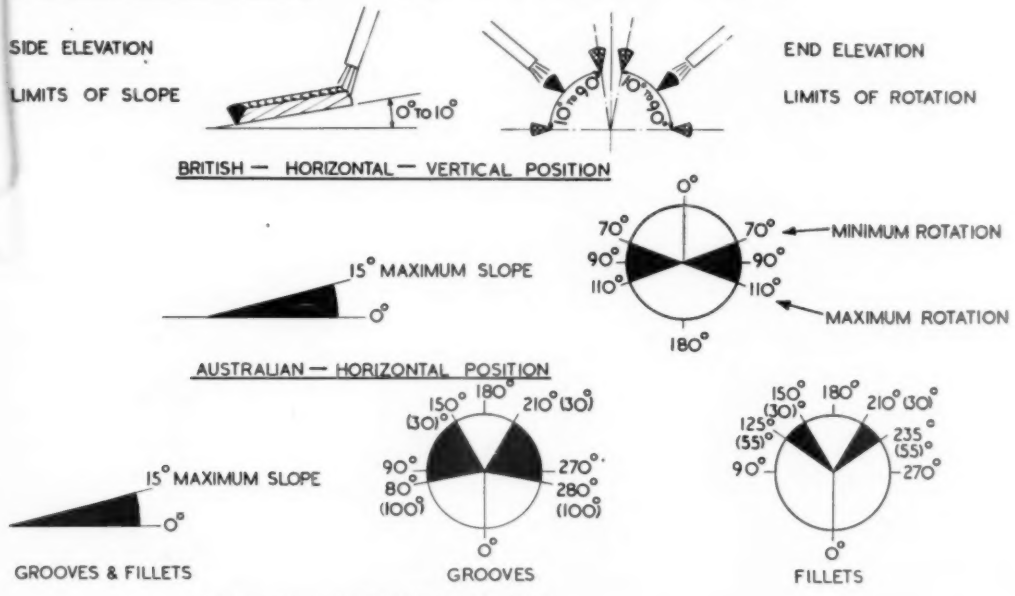

Fig. 6 Comparison of Group 5 welding positions

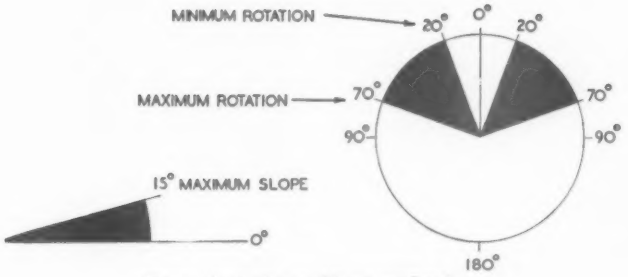

Fig. 7 Australian—oblique overhead

Group 6 (Fig. 7)

Oblique Overhead (Australian)	
Slope	0 to 15°
Rotation	110 to 155°

There does not seem to be any real need for this subdivision of the overhead position. Overhead welding technique is required to make welds in this position and both the British and American classifications designate them as overhead welds.

Group 7 (Fig. 8)

Overhead (British): Flat Overhead (Australian): Overhead for groove welds and Overhead for fillet welds (American).

The surprising point about these definitions is the wide variation in the angles of slope. It is not easy to understand why the Australian classification restricts the angle of slope to 15° when welds having a much greater slope, with this rotation, must be welded using overhead welding technique. Similarly, it would be extremely difficult to use the overhead welding technique for welds having a slope approaching 80° as designated by the American classification. The rotation limits of 55 to 180° permitted by the American classification for overhead fillet welds have a surprisingly wide range, not at all justified by the welding technique required to execute such welds in rotations less than 90° or with slopes greater than 45°.

	British	*Australian*	*American*
Slope	0 to 45°	0 to 15°	0 to 80°
Rotation	90 to 180°	155 to 180°	Grooves 100 to 180° Fillets 55 to 180°

GENERAL COMPARISONS

Salient features of the American classification are:

1. There are two demarcation points for angle of slope (15 and 80°) and six demarcation points for angle of rotation (150°/210°, 125°/235° and 80°/280°). These demarcation points for rotation correspond to 30, 55 and 100°, respectively, in terms of the other two classifications so, in effect, there are three divisions.
2. If the angle of slope is greater than 80°, the angle of rotation may be ignored as all such welds are classed as Vertical welds.

Salient features of the Australian classification are:

1. There are two demarcation points for angle of slope (15 and 75°) and four demarcation points for angle of rotation (20, 70, 110 and 155°).
2. If the angle of slope is greater than 15° the angle of rotation may be ignored. Welds having a slope between 15 and 75° are classed as Semivertical welds and those having a slope greater than 75° are classed as Vertical welds.

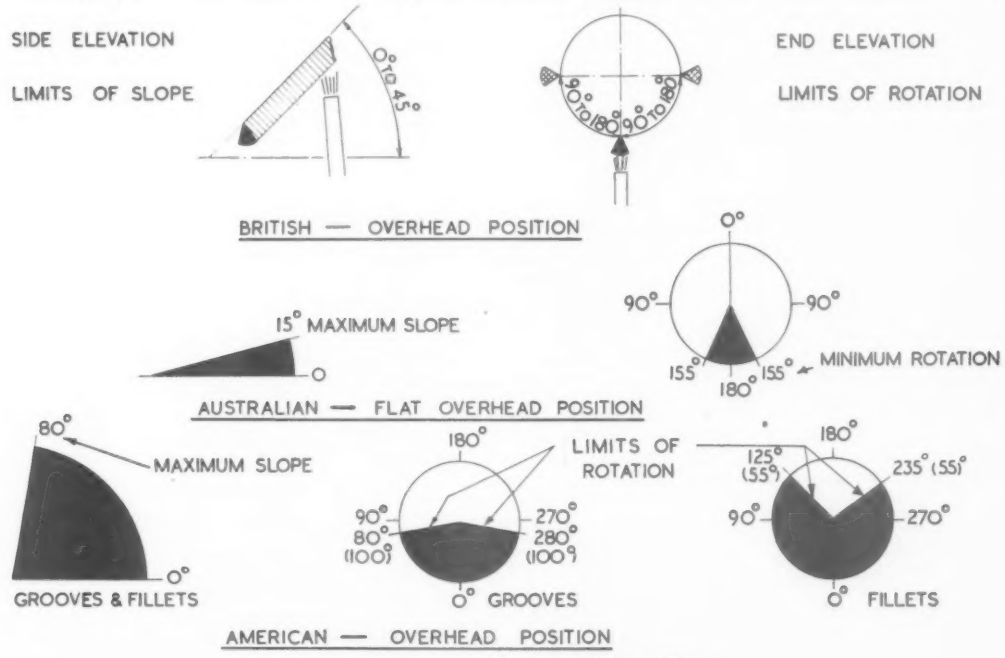

Fig. 8 Comparison of Group 7 welding positions

Salient features of the British classification are:

1. There are two demarcation points for angle of slope (10 and 45°) and two demarcation points for angle of rotation (10 and 90°).

2. If the angle of slope is greater than 45°, the angle of rotation may be ignored as all such welds are classed as Vertical welds.

3. If the angle of slope is less than 45° and the angle of rotation is greater than 90°, the weld is classed as an Overhead Weld.

4. If the angle of slope and the angle of rotation are both less than 10°, the weld is classed as a Flat weld.

CONCLUSION

The British classification, of which it has been written "that too much detail has been given to Welding Position,"[4] has succeeded in classifying every weld in one of five welding positions whereas the Australian classification specifies seven and the American, eight welding positions. The American classification is further complicated by the fact that groove welds and fillet welds are not classified alike in all definitions.

In the British classification, all definitions are based on one or more of three angles: 10, 45 and 90°. It is the opinion of the author that, in reaching this degree of simplicity in dealing with a difficult problem, there has been no sacrifice of clarity or confliction with customary welding practice.

This dissertation has shown how the leading welding authorities in three countries differ considerably in their assessments of correct definitions of welding positions. These very differences emphasize the necessity for proper definitions of welding positions and point to the need for an early resolving of views by the three authorities so as to remove some of the astonishing inconsistencies of the present classifications.

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Flexible Welded Connections for Structural Steel

New welded connections which are also suitable for semirigid and rigid framing are described and compared with the older types

by Emanuel Scheyer

THE bulk of structural steel work for buildings, especially multitier buildings, is constructed with simple or unrestrained connections between its members. While much publicity has been given in recent times to rigid-frame construction, which uses connections restraining the ends of joined members, such construction for buildings represents only a small percentage of the total, being used principally for airplane hangars and other buildings of one or two stories.

Welded connections specially designed for flexibility have been used heretofore. New welded connections are described in this paper which have certain advantages over those previously used.

Except for the lighter loads, where an unstiffened seat angle will do (Fig. 1), the present welded connections require a bracket (Fig. 3) under the supported beam. In many places there is no room below the supported beam for a seat angle or a bracket. This occurs where a beam frames flush bottom or early so to its supporting member (Fig. 12). In other cases where there is room for the bracket but the load to be supported is heavy, the bracket must be so large that it is unsightly. A structure having a maze of brackets is not as neat as one in which the end connections are inconspicuous.

The new connections are suitable for both light and heavy loads, though especially so for heavy loads. They lie flat against the support and require no brackets even for heavy loads. Because of the new connections, it should be possible to produce improved welded structures; also, welded construction can be substituted for riveted construction in situations where, heretofore, welding would involve troublesome complications.

While primarily intended for simple framing, the new connections are also of value for semirigid and rigid framing.

A novel feature of the new connections is their deliberate weakening along one or more lines so that they will bend readily along these lines when flexed by the deformation of the beams they support and thus relieve the connecting welds of excessive secondary stress. Weakening of the connections is only resorted to in special situations. Usually, the connections are inherently flexible enough to bend readily without resorting to weakening them along the bend lines.

Connections between beams and between beams and columns, for simple and unrestrained support, must be flexible, especially where welding is used instead of riveting. Under load a beam bends, its upper portion at the end tending to pull away from the support. Riveted connections have inherent flexibility, their end connection angles deforming and even the rivets and the metal against which they bear giving way somewhat as the beam which they support bends when loaded. This deforming and giving way is self-limiting in that once the beam has bent and its connection has deformed, no additional stress producing action can take place. In fact, if the connection is permanently stretched or deformed beyond the elastic limit, the stress is largely decreased. It would not do with welding to weld the web of the supported beam directly to the support. The size of the weld being only a fraction of an inch across, there is not enough metal in the weld to permit the stretch required to allow for the deformation of the end of the supported beam. Even though the stretch is small, it is large, relatively, to the cross section of the weld.

PRESENT CONNECTION TYPES

The present connection types described below are those recommended by the American Institute of Steel Construction.

A welded connection for simply supported beams with relatively light reactions is shown in Fig. 1. There is disagreement as

Emanuel Scheyer is Designing Engineer, Engineering Department, Board of Transportation, New York, N. Y.

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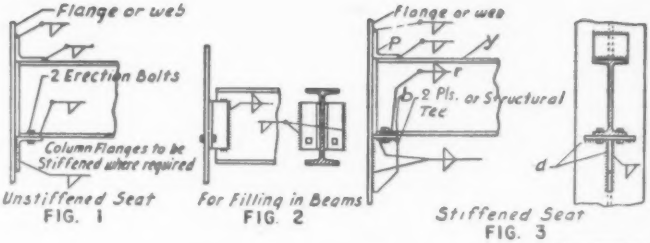
to the maximum load that should be supported by this seat angle connection. In the opinion of some, the maximum reaction should not be over 35,000 lb.

Another connection for light loads, such as are carried by the filling-in beams of a floor system, is shown in Fig. 2. Each angle of a pair of connection angles is shown welded along its vertical edges to the web of the supported beam and to the support.

Where relatively heavy loads are to be supported, the recommended connection is as shown in Fig. 3. This connection comprises a bracket having a seat reinforced with a stiffener. The bracket can be made from a split beam. It could also be built up by using a stiffener plate coming under a seat plate. The use of such a connection produces loading eccentricity on the support, especially if not balanced by a symmetrically disposed load on the opposite side of the support, and the welding, *d*, between the bracket and the support is subjected to a moment. The welding, *r*, between the bottom flange of the supported beam and the top of the seat is subjected to a prying action because the beam when deformed under load tends to lift off the seat. While welding, *r*, is of secondary importance in simple framing, it is of prime importance in semirigid and rigid framing. Also, the top angle, *p*, which is of importance in semirigid framing, is subject to an upward prying action due to the upward thrust of the top flange of the beam as its bottom flange tends to rotate about the edge, *b*, of the bracket as a fulcrum. Similarly, in rigid framing, the usual butt weld, not shown, at the top of the supported beam and the column is subjected to prying uplift. The eccentricity of the load on the bracket is augmented by the fact that the beam, when it deforms, tends to bear on the outer end, *b*, of the seat which in turn makes critical the crippling or buckling of the web of the beam. Assumptions must be made as to this stress which is highly indeterminate.

A further objection to the use of a bracket or stiffened seat is that its stiffener often interferes with the finish or fireproofing around its support, as where it is on the flange of a column, because the stiffener sticks out from the column through the usual two inches of concrete fireproofing. This requires the concrete to be stepped out around the stiffener. Brackets also detract from the neatness of a structure where the steel is exposed. One gets the feeling that he might bruise his head against the bottom edge of the bracket.

In semirigid framing, a top angle, *p*, is required to supply a partial fixing moment. Even in simple framing, where no fixing moment at the support is desired, a top angle, such as angle *p*, is required. As will be shown, this is unnecessary in the new type unless semirigid framing is desired. In a seated connection of the present type, in simple framing, as well as in semirigid framing, the top angle provides lateral support for the beam until such time as the floor slab has been installed.



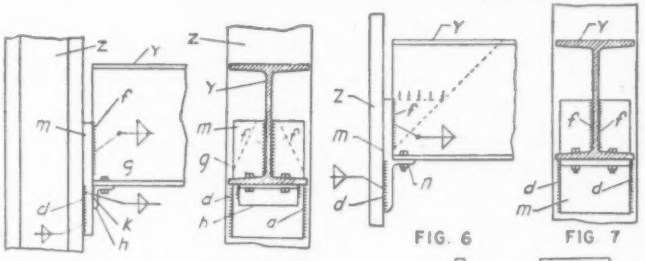
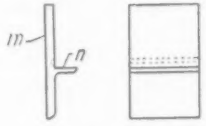
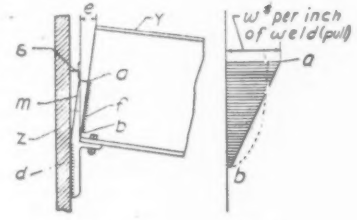
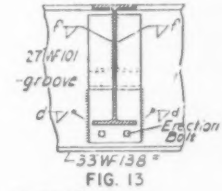


Plate Connection with Sufficient Welding Depth below Bottom of Supported Beam.







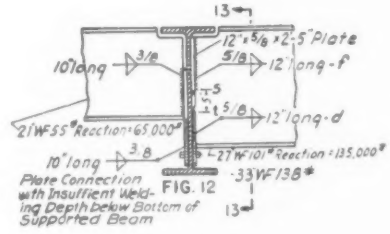
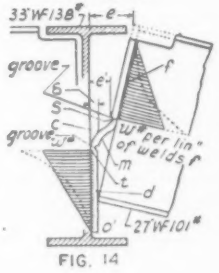


Plate Connection with Insufficient Welding Depth below Bottom of Supported Beam



NEW CONNECTIONS

The basic element of the proposed connections is a flexible plate interposed between the web of the supported beam or girder and the face of the support. The type shown in Figs. 4–11 is adapted for framing into a column, a web of a beam, or other suitable vertically extending supporting element when there is room enough below the bottom flange of the supported beam for the plate, *m*, to extend down for the full length of the welding, *d*, to the support.

The plate, *m*, is shop welded to support *z* by means of welds *d* which are of sufficient length and size to transfer the reaction of supported beam *y* to the support. Beam *y* is field welded to plate *m* by means of welds *f* which are also sufficient to take the reaction of the beam. Bolts *g* and seat angle *h* (Figs. 4 and 5) are provided solely for erection. For this purpose, it

is to be noted that unlike the standard seat angle connection of Fig. 1, welds *k* need only be sufficient to take the dead weight of beam *y*.

Instead of using a plate, such as plate *m* with a welded-on erection seat angle, *h* (Figs. 4 and 5), a specially rolled T-section, as shown in Figs. 6–10, could be used, which would eliminate the seat angle, *h*, and its welds, *k*. The vertical plate portion, *m*, of the rolled section is in place of plate *m* (Fig. 4), and the outstanding stem, *n*, provides the erection seat. Should this type of connection be generally accepted, the demand might be sufficient to warrant special rolls for its production. To suit different loads, a series of a few different standard sized T's would be produced in continuous lengths, as is now done with connection angles for riveting, the designer selecting the nearest size for his beam reaction requirements. The continuous lengths of this T received from the mill would be cut to individual lengths in the fabricating shop to suit the connections as shown on the detail drawings; however, where very heavy loads must be supported and the vertical length of plate *m* becomes too great, say over 20 in., the rolled T's would not be used, but a separate plate and seat angle would be employed as in Figs. 4 and 5.

For simple framing with the new connection, the top angle, *p*, of the old type, shown in Fig. 3, is not required, as plate *m* (Figs. 4 and 6) supplies lateral bracing to the web of the supported beam. As noted before, with the old type of seat angle framing, the top angle is supplied for lateral bracing until such time as the concrete for the floor slab is poured. The new connection is advantageous in preventing web buckling (see welds *f*, Fig. 5), particularly important nowadays because of the introduction of wide flange beams which have relatively thin webs. With the old or seated type of connection, where a heavy beam reaction must be supported by a stiffened seat, the width of the stiffener, that is, the amount it projects out horizontally from the column, must be sufficient to provide bearing under the beam. The projection of the stiffener introduces eccentricity on its welds, *d*, Fig. 3, requiring the stiffener to be increased in depth to provide additional length of welds. A further consideration is that this eccentricity is increased when the beam deforms under load, the deformation, as explained before, causing the bearing of the beam on the seat to move out from the face of the column toward edge *b*. All these factors are eliminated with the new connection as no provision for bearing is needed, the reaction being carried by welds *f*, Figs. 4 and 5, along the vertical edge of the web. The new connection lends itself more readily to skew framing for heavy loads than the older type of Fig. 3. In the latter, the web of the supported beam must come over or be in substantial alignment with the stiffener of the seat below for proper bearing. With the new type, the load is transferred to the support by welds, *f*, even at an angle.

By way of example, beam *y*, Figs. 6 and 7, will be considered to be a 36-in. WF 170-lb. beam with a reaction of 80,000 lb. Welds *f* and *d* will be chosen as $^1/_2$-in. welds. According to standard welding practice, a $^1/_2$-in. weld is good for 4800 lb. per linear inch. Noting that there are two welds *f* and two welds *d*, their length to take the beam reaction will be made 9 in. Welds *f* transfer the beam reaction to plate *m* and welds *d* transfer it from plate *m* to the support *z*. Considering the compressive stress to spread out in an upward direction in the web at 45° from the bottom of welds *f*, Fig. 6, the total load is transferred to the web by the time the top of the welds is reached and is spread out there a horizontal distance of 9 in. The load being 80,000 lb. and the web thickness 0.68 in., a maximum compressive stress of 13,000 psi. is produced in the web at the top of welds *f* which is well within the 24,000 lb. usually allowed for web crippling. Above the top of welds *f*, the load fans out further, thereby rapidly reducing the intensity of compressive stress in the web.

When beam *y*, Fig. 10, is deformed under load, it pulls plate *m* with it away from the support. This induces tension stress in welds *f* and bending stress in the plate, which latter stress is superimposed upon the compressive stress to which the plate is subjected from the reaction of beam *y*. This combined bending and compressive stress, stresses the plate *m*, which is an 11-in. by $^3/_8$-in. plate, beyond its elastic limit, causing it to yield. The overstress in the plate is self-limiting and disappears when the plate takes a permanent set.

The tension stress induced in welds *f* by the deformation of beam *y*, which is resisted by the bending strength of plate *m*, is assumed to be as shown in Fig. 11, being a maximum at *a* and substantially zero at *b*. This distribution of pull on welds *f* is true only if plate *m* is assumed to be absolutely stiff above the bend line of the plate, which line is located somewhat below point *b*. Actually, since plate *m* is flexible, the stress at *a* will be less than shown and will be more toward *b* as shown by the dotted line. The usual flexural theories have to be applied with caution here. Tests are indi ated for a better determination of stress behavior. If necessary, horizontal welds can be added at the intersection of the top of the bottom flange of beam *y* with plate *m*. It is to be noted that there is considerable lateral distance between welds *f* and welds *d*, Fig. 7. Because of this distance, there should be enough metal present to provide for the necessary deformation or give required of plate *m* without undue pull on welds *f*. This distance is the equivalent of the length factor in Hook's law; however, if excessive pull, in any given case, is developed in welds *f*, plate *m* can be deliberately weakened in bending by removing some of its metal in the form of a groove at the bend line (see dotted lines in Figs. 8 and 9). This weakening is more fully explained later on in connection with Figs. 12, 13, and 14. If the rolled section of Figs. 6 and 7 should come into general use, the weakening line or groove could be rolled in the section during the operation of rolling the section itself.*

For the particular example chosen, a calculation would show that the maximum stress or pull on welds *f* theoretically is 80 lb. per linear inch for each of welds *f* to bend plate *m*, there being two such welds, one on each side of the web. Such a stress is negligible compared to the shear of 4800 lb. per linear inch taken by these welds to support the reaction of beam *y*.

NEW CONNECTIONS ESPECIALLY SUITABLE FOR HEAVY LOADS

According to present practice, a bracket such as shown in Fig. 3 would be used to support a beam *y* having 80,000 lb. reaction. A suitable bracket would comprise a plate 9 in. deep, $3^1/_2$ in. wide and $^{11}/_{16}$ in. thick, using $^1/_2$-in. welds. In addition, there would be a seat plate and a 4- by 4- by $^1/_4$-in. top angle with their appropriate welds. It is obvious that from a cost viewpoint there would be little or no saving here in using the new type connection in place of the present type, but there are other advantages as noted before. Some of these advantages become particularly apparent where heavy loads must be supported. Consider the member *y* in Fig. 3 to have a reaction of 210,000 lb. A bracket to support such a load offers serious difficulties in bearing. Assuming member *y*, which might be a welded plate girder, to have a $^3/_8$-in. thick web, a safe bearing stress would require the bracket to be 23 in. wide. With $^5/_8$-in. welds *d*, it would have to be 27 in. deep. This would be a very clumsy looking bracket. If used for the support of the girders for a large bus garage, four acres in extent, now being built in Brooklyn for the Board of Transportation, it would present a veritable forest of brackets. Even in smaller structures, brackets are unsightly, and where the columns are fireproofed, the concrete encasement must be specially brought out around the brackets. Deep brackets might encroach upon the headroom in many structures, and unless blocked off from access below, will constitute an element of danger. Large brackets, because of eccentricity, require more metal to be provided in the supporting columns to take care of inequality of load in adjacent panels, especially where the live load is large. One panel may be fully loaded and the adjacent one empty.

In contrast to an unsightly projecting bracket, the new connection is perfectly

* Patent No. 2,382,583.

flat against the column no matter how great the load. The new connection is as unobstrusive as the end framing angles in riveted construction.

In the above discussion, a load of 210,000 lb. was considered, and it took a plenty large bracket to support it. But 210,000 lb. is not really such a heavy load considering those met with in steel structures. For very heavy loads, a bracket is unsatisfactory, if not impracticable, but a flat plate would seem to have no limit.

CUTTING TOLERANCE

The new type of connection requires the beams to be cut closer to their theoretical length than is required of riveted construction or than is required of welding using present standard connections. Where there is a sufficient cost saving over riveting and where there are other advantages for the new welded connection over the old welded type, they offset the added cost required for closer tolerances. In welded construction, in situations where the new connection makes welding feasible, the added cutting cost is no factor. Even in situations where the new connection only improves the appearance of welded construction, the added cutting cost should not be great enough to prevent its use.

The usual practice in riveted construction where beams frame between metal to metal, is to order the beams from the mill $^1/_2$ in. shorter than their theoretical length, and to detail them so that their end connection angles have $^1/_{16}$ in. clearance from the support at each end, making the fabricated beam $^1/_8$ in. short. The reason for ordering the beams $^1/_2$ in. short is because the mill cuts them with a tolerance of $^3/_8$ in. This varies somewhat, depending on the size and length of the members. Riveting practice tolerances while suitable for the present standard welding framing are unsuitable for the new type because there is no good way to make up for underruns of too great extent below the theoretical length. With riveted construction the underrun is made up by setting out the end connection angles.

As seen in Figs. 4 and 12, the supported beams have their webs directly connected by welds *f* to the connection plate which in turn is welded to the support by welds *d*. Present welding specifications sanction welding across a maximum gap of $^3/_{16}$ in. It is thus seen that a beam will not do if too short. To allow for the mill tolerance of $^3/_8$ in., they must be ordered that much longer than their theoretical length plus an added length for milling later to bring them close to their theoretical length. The cost of milling beams both ends averages about $3.50 per ton.

During the war, automatic flame cutting was used extensively for ship's plates. Apparatus for doing this has been brought to a high state of perfection. It is believed that if the new welded connections, should become generally used, the structural shops would feel warranted in introducing flame cutting technique to cut beams to close tolerance at a considerably smaller cost than $3.50 per ton.

INSUFFICIENT DEPTH FOR WELDING OF SUPPORTED BEAM

The new plate type of connection is particularly suited to situations where heavily loaded beams must frame into headers or supporting beams of approximately the same depth. An analogous situation occurs where the bottom flange of the supporting beam is flush with or cannot come more than a few inches below the bottom flange of the supported beam. Under these conditions, the standard type of welded framing (Figs. 1 and 3) cannot be used as there is insufficient space to provide either a seat angle or a stiffened seat.

The conditions noted above occur at practically all the stations of the New York City subway system. Figures 12 and 13 show the new type of welded framing if it were applied to the beams over the platform of a subway station. The new welded plate connection shown in Figs. 4 and 5 is unsuitable because enough space is not present for welds *d* to come below the bottom flange of beam *y*. In the new welded plate connection, modified to suit the conditions shown in Figs. 12, 13, and 14,* a large part of weld *d* comes so high as to be opposite the 27-in. supported beam. This completely changes the stress picture from where there is space for welding below the beam. Not only is the stress in welds *d* and *f* different, but in plate *m* also, in that it is subject to reverse bending with a point of contraflexure at *c* midway between welds *d* and *f*. The closer these welds are spaced vertically to each other, the greater will be the pull required of them to bend plate *m*.

Plate *m* can be considered for the purpose of stress analysis to be composed of two cantilever plates with their free ends located at the point of contraflexure, *c*, with the pull due to the deformation of the supported 27-in. beam applied at *c*. The deflection, delta, at *c* can be taken as equal to half the distance *e'* which is the distance that the supported beam pulls away from its support at *s*, the bottom of welds *f*. The distance *e'* can be readily calculated from well-known structural theory. To take at 20,000 psi. compression, the 135,000-lb. reaction of the 27-in. beam, a 12- by $^5/_8$-in. plate will be used, and welds *d* and *f* will be $^5/_8$-in. welds, each 12 in. long, remembering that there are two welds *d* and two welds *f*. Theoretically a $^5/_{16}$-in. plate would do, but $^1/_2$ in. is used because of the $^5/_8$-in. welds. By basing the stress calculation on the stress diagram of Fig. 14, it is found that the maximum tensile stress, *w*, is 4630 lb. per linear inch for each one of the two welds *d* and each one of the two welds *f*. When this stress is vectorially combined with the 5600 lb. per linear inch required of these welds to take the shear of 135,000 lb. from the beam, it is found that the welds must take a maximum stress of 7280 lb. per linear inch, whereas $^5/_8$-in. welds are supposed to take only 6000 lb. per linear inch. If the welds were made longer than 12 in. in order to decrease their shear stress, the distance between *t* and *s* would become less than 5 in. (Fig. 12), for which the above stresses were calculated. Recomputing for this decreased distance would show that *w* is greatly increased. The distance, *ts*, is very critical. The reason for this is that for the same deflection, delta, at *c*, the cantilever arms *tc* and *cs* are varied. The load required to produce a given deflection, delta, varies as the cube of the cantilever arm. Therefore, it is desirable to keep the distance *ts* large. For example, if the supporting beam, that is, the 33-in. beam in Fig. 12, were made a 36-in. beam, the distance *ts* could be increased. Even if it were made only 7 in. instead of the 5 in. used, the combined stress in the welds due to shear and tension would be 6000 lb. per linear inch which is permissible for a $^5/_8$-in. weld. Blocking back the unwelded lower portion of the 27-in. supported beam at its ends (Fig. 14) would prevent these ends from binding against the surface of the supporting plate *m*, when the beam deforms under load, thereby further preventing secondary stress.

DELIBERATE WEAKENING OF WELDED CONNECTION PLATES

As noted above, the set up shown in Figs. 12, 13 and 14 induces theoretically a maximum stress of 7280 lb. in welds *d* and *f* which is greater than the allowable. Actually, the maximum stress is even greater due to the flexibility of plate *m* opposite welds *d* and *f*. A considerable concentration of stress will occur at *t* at the top of welds *d* and at *s* at the bottom of welds *f* as shown by the dotted lines in Fig. 14.

In order to reduce the secondary stress in welds *d* and *f*, which stress is due to the resistance of plate *m* to the bending required of it by the deformation of the 27-in. beam (Fig. 14), the plate is deliberately weakened in bending. The weakening is effected by grooving the plate to about two-thirds of its depth along a line just below welds *f* and along another line just above welds *d*. To avoid undue concentration of stress, the grooves are semicircular. They are located inward from the bending compression side of the plate so that when the plate bends, the grooves tend to close up, rather than cause tearing of the plate as might be the case if they were located on the bending tension side. The grooves are shown on opposite sides of plate *m* because it is subjected to reverse bending.

By weakening the plate, it is readily de-

* Patent No. Re 22905.

formed beyond its elastic limit, relieving the welds thereby of much secondary stress when the supported beam has its self-limiting deformation.

Weakening the plate can be avoided in many cases by increasing the size of the welds. It must be determined in any particular case whether it is more economical to weaken the plate. As noted before, weakening can also be avoided if the distance *ts* between the welds can be made large enough.

Even if the calculations show, in a given case, that excessive pull on the welds is not developed and, therefore, weakening of the connecting plate is not required, there might be an advantage in weakening it along bend lines to localize the bending and thus eliminate possible indeterminate stresses in the welds. Full size tests are warranted to determine this point. The plate can be weakened in other ways than by grooving, such as by punching a row of holes along the bend lines.

Incidently, attention is drawn to what is believed to be an improvement in standard welding symbols. The arrow head is omitted from the end of the lead line of the weld symbols, such as the lines in Fig. 12 relating to welds *d* and *f*. This lends clarity, as the arrow heads tend to run into other lines of the drawing.

PARADOX OF WEAKENED SECTION

For the 135,000 lb. reaction of the 27-in. beam of Figs. 12, 13 and 14, a $^3/_8$-in. thick plate is required to carry the load in compression from upper welds *f* to lower welds *d*. Such being the case, the question will be asked, if this be the thickness required, how is it possible to reduce it at the bend lines to $^3/_8$ in. or about two-thirds of its original thickness to enable the plate to bend readily to prevent excessive secondary stress in the welds. The answer is to be found in the different stresses allowable for different conditions of lateral support for compression members. Where compressive stress is applied to a long member without lateral support to prevent it from bulging, the column formula is used. For shorter lengths without lateral support, a higher stress is suitable than allowed by the column formula, and for very short unsupported lengths, a still higher stress is permitted. In a generally accepted column formula, a stress is permitted graduated down from 17,000 psi., in accordance with the increase in unsupported length. For shorter lengths, as with stiffeners, 20,000 psi. is generally used, and for very short lengths or bearing, 30,000 lb.

Due to the relative location of welds *f* and *d*, the allowable stress in plate *m* can be taken as 20,000 psi., as with stiffeners, except at the grooves. At the grooves, the compressive strength can be taken as a bearing stress of 30,000 psi. because of the backing of the adjacent thicker metal above and below and because of the very short vertical extent of the grooves. The ratio of 20,000 to 30,000 is two-thirds, hence the statement, previously made, that the plate can be reduced to two-thirds of its original thickness at the grooves.

If instead of being grooved, the plate were weakened by holes at the bend lines, it could be reduced there to two-thirds of its cross-sectional area. However, grooving the plate is much more effective than holes in reducing its resistance to bending and hence in reducing the secondary stress on the welds. The resisting or bending moment of the plate varies as the square of its thickness, which is reduced in grooving, whereas the resisting moment varies only as the first power of the area of the plate whose depth is unchanged when it is weakened by holes.

The type of connection, shown in Figs. 12, 13 and 14 for the 27-in. beam, makes "simple" framing welding practicable where two members of nearly the same depth must frame into each other or where, regardless of relative depth, they must be flush bottom or nearly so. It makes possible the use of welding at subway stations, where the longitudinal platform beams are only slightly lower than the transverse beams which frame into them. Welded steel framing for subways between stations, which is entirely different because of the absence of the longitudinal platform girders, has already been suggested by the writer in his paper "Welded Steel Bents for Subways," which paper forms a chapter in the book *Studies in Arc Welding* published by The James F. Lincoln Arc Welding Foundation.

The connection of Figs. 12–14 should prove of value for welding the floor beams to the longitudinal girders of through bridges. Look at the 27-in. beam in Fig. 12 inverted, interchanging welds *d* and *f* and locating the erection bolts at the bottom of the inverted figure.

Where saving in headroom is important, it becomes essential that headers and the beams framing into them be of substantially the same depth, a situation to which the new connection of Fig. 12 is especially adapted.

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(*Continued from page 221*)

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Controlling Cutting Tip Clearance

Advances in production requirements call for a machine that will follow irregular surfaces, will operate at high speeds and will not be affected by high temperatures

by H. G. Hughey and R. B. Steele

A COMMON sight in present-day industrial plants is the mechanically operated oxygen cutting machine, following a predetermined path over the surface of steel plate and automatically producing shapes of desired form. The operator is free to observe the performance of the equipment and to make such minor adjustments as will assist in procuring a good product.

Advances in production requirements have introduced problems beyond the scope of the usual machine, which was designed to operate over flat, cold material at moderate speeds. These advances require a machine that will follow irregular surfaces, will operate at high speeds and will not be affected by the high temperatures normally encountered. Since the basic requirement is a device that will automatically maintain tip clearance, let us follow that problem through to its ultimate solution and at the same time show how the other requirements are met.

To appreciate the conditions encountered when cutting over such surfaces, let us refer to Fig. 1 as an example. To produce the best type of results, the tip should remain reasonably uniform in distance above the surface during operation. In this example, the torch must rise and fall steadily in keeping with the surface contour, and most machines are not equipped to impart this motion. The operator must provide manual adjustment. It is true, of course, that for specific production, special devices have been evolved which will impart the desired vertical motion.

Briefly referring to such attachments, it will be found that wheels or drags in

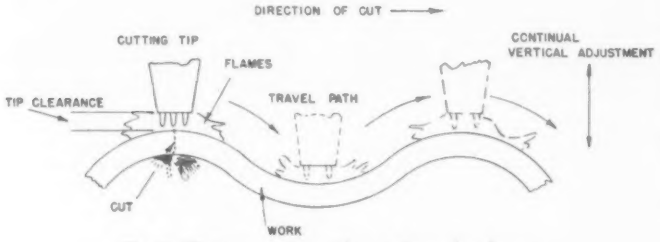


Fig. 1 Tip traverse in cutting on irregular shapes

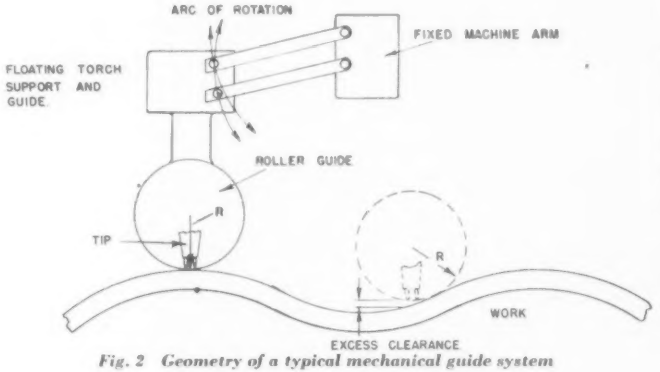


Fig. 2 Geometry of a typical mechanical guide system

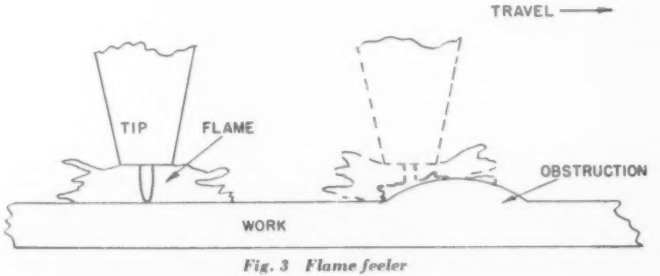
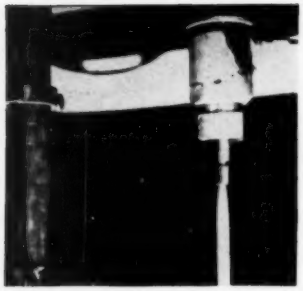


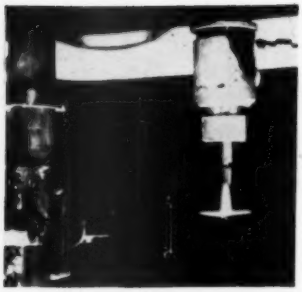
Fig. 3 Flame feeler

H. G. Hughey, Research and Development Engineer, and **R. B. Steele,** Assistant Research and Development Engineer, Research and Engineering Dept., Air Reduction Co., New York, N. Y.

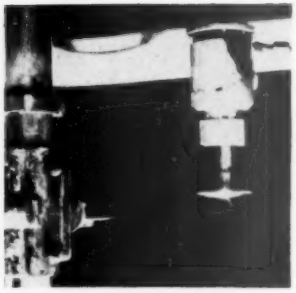
Presented before the Twenty-Ninth Annual Meeting, A.W.S., Philadelphia, Pa., week of Oct. 24, 1948.



No Impingement

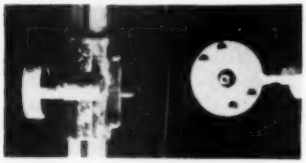


Slight Impingement

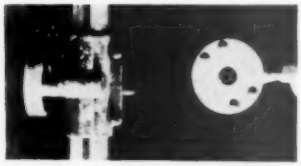


Severe Impingement

All Light



Black Spot in Center of Light



Narrow Light Ring Large Black Center

Fig. 4 Photograph of flames

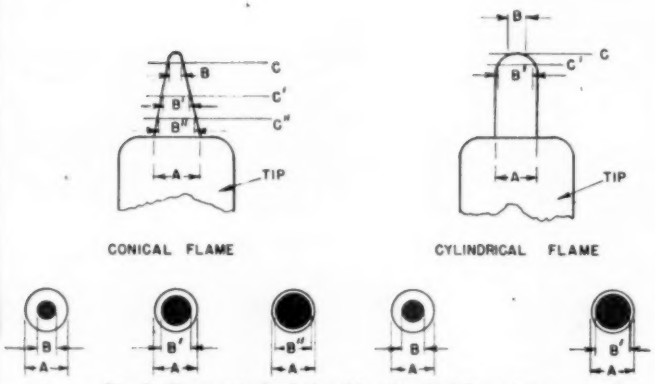


Fig. 5 Geometrical relationship of typical flame types

contact with the surface constitute the most general approach. The torch floats vertically, being moved by the action of the guide. Geometric problems are posed, Fig. 2, since the spacing is controlled by the roller radius, *R*, which is not always on the vertical axis, whereas the tip clearance always lies on the vertical. Clearance will be in excess of *R* in most relationships, and will be variable. Other factors affecting the free motion of the wheel and the flotation of the torch are heat, slag and mechanical limitations.

A recent development provides a spacing device which avoids mechanical surface contact, is unaffected by heat and has minimum geometric problems. The spacing device comprises a flame (inner cone), Fig. 3, of conventional type which "feels" the work surface, so to speak. Any rise or fall of the surface is detected by this flame feeler, which sends a message to an electronic control system that accurately positions the torch.

The flame, as generally pictured, assumes a somewhat conical form, of color ranging from orange for the hydrocarbons with deficient oxygen, through the blue-green for oxygen-hydrocarbon, down to nearly colorless for the oxygen-hydrogen. For the present purpose, however, we view the flame from the rear, Fig. 4. If we observe the flame through a transparent medium, this rear view will disclose a circular spot of light in size equal to the orifice diameter, Fig. 4 (*a*). Let us lightly impinge this flame against a surface, Fig. 4 (*b*), and there will appear a small black spot in the center. The degree of impingement will determine the size of this black spot, and it may be so large as to virtually eliminate any light, Fig. 4 (*c*). The geometric relationships are simple, being portrayed in Fig. 5 (*a*). For a conical flame issuing from an orifice of diameter *A*, impingement at levels *C*, *C'* or *C''* will result in black spots of

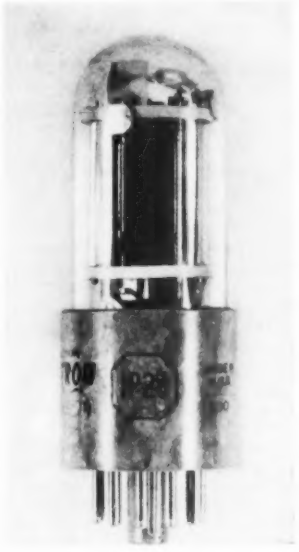


Fig. 6 Photo tube

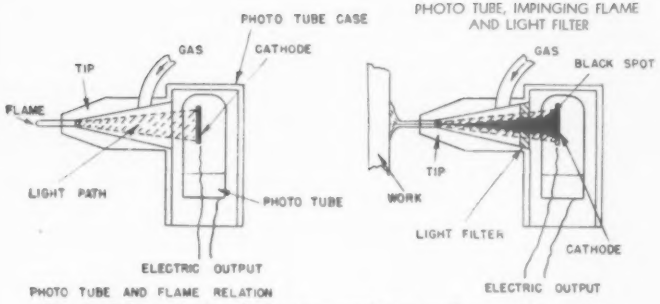


Fig. 7 Schematic detail of energy producing and converting system

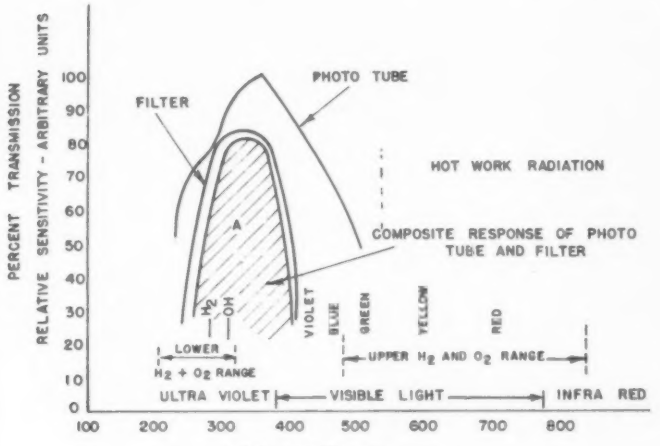


Fig. 8 Light characteristics of system

diameters B, B' or B'', respectively. Other flame shapes, Fig. 5 (*b*), provide different geometric detail and have special significance with respect to operating characteristics.

The message previously mentioned arises from a change in energy which starts in the form of light and, through transformation, finally becomes electrical energy. Thus, with an impinging flame at one condition, a specific level of light energy exists, and any change will tend to alter this energy level. With an electronic system stabilized for the initial condition, any tendency toward instability by a changing energy relationship is resisted; in this case by moving the torch until the initial condition is re-established.

Transformation of energy is accomplished by means of a photo-tube, Fig. 6. This device, in outward appearance not unlike most electronic tubes, has a cathode which will develop electron emission or electrical energy if a light beam is directed upon it. The energy output is in proportion to the energy in the light beam. The heart of this entire system then comprises the energy producing element of flame, and energy transforming element or photo-tube, Fig. 7 (*a*).

The practical application of these units requires that cognizance be taken of certain details, most prominent of which are (1) an unimpeded optical path, (2) control of flame dimensions, (3) sealing of combustible gas from the photo-tube chamber, (4) water cooling for hot work, (5) selected materials and (6) selection of light of proper characteristics. The last-mentioned detail merits particular consideration.

Light can originate from both the flame and a hot workpiece, but only the flame is subject to control. Secondary light from the work is undesirable, and is, therefore, eliminated by interspersing a filter in the optical path, Fig. 7 (*b*). However, to avoid also eliminating the flame effect, it

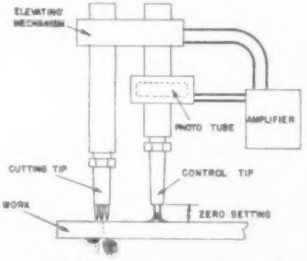


Fig. 9 Schematic of control system

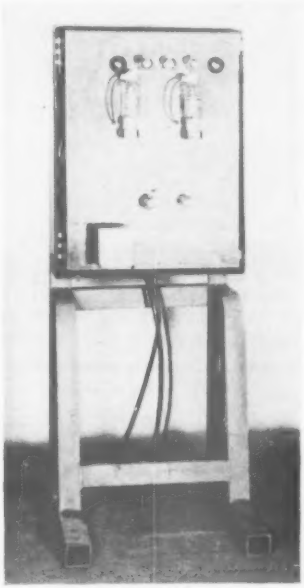


Fig. 10 Control box

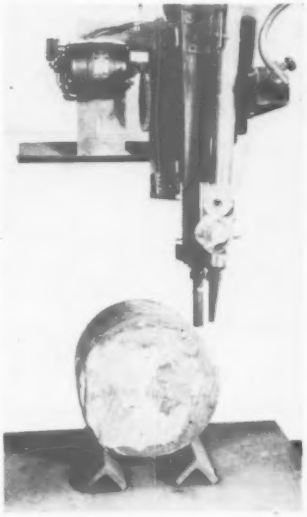


Fig. 11 Control unit with cutting torch and work

becomes necessary to consider light in the ultraviolet range, selecting gases which produce in combustion substantial quantities of such light. Hydrogen, Fig. 8, with strong bands at 270 and 306 mμ and a general output from 240 to 320 mμ is well suited. The complete system is so balanced in characteristics that the filter and photo-tube then eliminate visible and infrared light. The resultant usable energy is shown as the shaded zone *A* in Fig. 8.

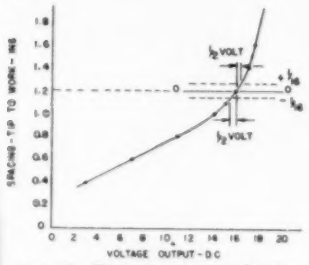


Fig. 12 Typical response of a tip

With a specific source of energy established through the optical detail, the resultant electrical energy must be made to do useful work. From the photo-tube, the energy is introduced into an electronic system which terminates with a servo-unit to move the torches, Fig. 9. If the control tip is set so that the flame impinges on the work to a definite degree (say *C'*, Fig. 5) there will exist a definite energy output. The electronic system uses this point as the zero point. If the energy tends to increase from more light input due to the control tip and work separating, the electronic balance becomes upset in a direction which causes the servo-unit to lower the torch. A parallel but upward action occurs if the tip and work move toward each other.

The general view of the electronic control box is shown in Fig. 10, and of the torch in relation to a cutting operation in Fig. 11.

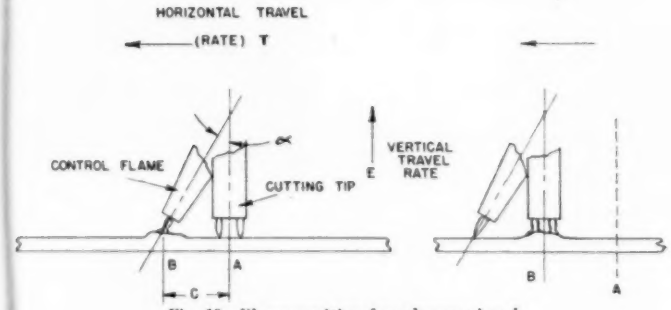


Fig. 13 Flame position for advance signal

The application of this device imposes no change in the cutting torch or tip or in the technique of operation. It becomes an auxiliary device that can be activated or not as required. Once it is adjusted for the initial or zero condition, the traverse of the torch across the surface is automatically maintained in correct height relationship to the work. Depending upon operating requirements, sensitivity can be adjusted to allow for passage over small obstructions without response, thereby removing the tendency to continually "hunt." If desired, the device can be made to operate only when obstructions become of specified height. Typical response characteristics are shown in Fig. 12. In this case, with an initial control tip clearance of 1.2 in., and with the electrical system responsive to ½ v. minimum change, an interference less than 1/16 in. would have no effect.

Various mechanical adjustments assist in establishing a versatile unit. To compensate for inertia lag in starting the torch in motion, the control flame can be projected angularly in a forward direction. For example, Fig. 13, an obstruction at *B*, registers on the control flame causing the torch to elevate. By the time the torch has traversed the distance *A–B*, the cutting tip is in proper relationship. Such functions of vertical travel rate, *E*, horizontal travel rate, *T*, and distance, *C*, are of particular interest in high-speed work, in effecting running starts and in determining the steepness of slope that can be traversed. An added safety element lies in automatic elevation should the control flame become extinguished.

A wide range of surfaces can be made responsive to this device, most of which otherwise require manual or special treatment. In Fig. 14, there are indicated several typical and common arrangements. In addition to surface response, protection is provided against inadvertent obstruction such as a warped plate, twisted scrap from cutting or an over-looked tool.

This method and equipment as outlined provides a nonmechanical surface guide sufficiently versatile to accommodate almost all conditions normally encountered. Its basic principles of design were directed toward use under severe conditions such as hot and fast work where limits now exist in the effectiveness of manual control and which do not justify complex mechanical devices. While cutting has been used as the application example in this article, the device is not restricted. Application of flames to other services in our industry suggest that this type of control can be used under other conditions requiring constant relationship to a surface contour.

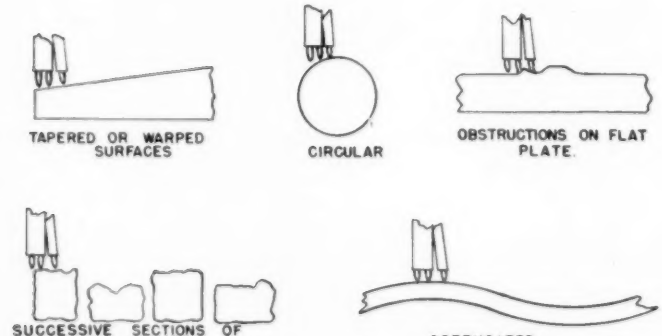


Fig. 14 Typical sections which are responsive to automatic height control

Silver Alloy Brazing Beryllium-Copper Alloys

As-received solution-treated material can be low-temperature silver alloy brazed and subsequently aged for one to three hours at 600° F. to obtain desired hardness

by A. M. Setapen and W. D. Warren

BRAZING of beryllium-copper alloys with low-temperature silver brazing alloys has not been extensive. This is due principally to the belief that a reasonably high degree of hardness is not attainable after heating to 1200–1300° F. for silver brazing.

The previously published recommended silver brazing procedure combines brazing and solution treatment by joining beryllium-copper parts with a silver brazing alloy that flows at 1435° F. After the parts have been heated, usually in a furnace, to 1450° F. and the alloy flowed through the joint area, the furnace temperature is reduced to 1400° F. to solidify the brazing alloy and the assembly is then quickly quenched in cold water. Aging the quenched assembly for 3 hr. at 600° F. precipitation hardens the beryllium-copper to the range of Rockwell C 33–37 (Rockwell 30N = 53–57). Successful use of this method of brazing depends to some degree on the previous treatment of the beryllium-copper, on the time at brazing temperature and on the rapidity and completeness of the quench.

It is probably safe to say that most of the beryllium-copper strip and rod that is currently used in assemblies, where joining by soldering or brazing is to be considered, is supplied in a solution-treated and cold-rolled condition that will withstand most of the usual blanking and forming operations. It is only necessary to age the blanked or formed parts at 600° F. for an hour or two to develop maximum hardness and spring properties.

The combined brazing and solution treatment at 1450–1400° F. is a repetitious operation which may or may not develop the desired physical properties on subsequent age hardening.

The purpose of this paper is to present data on a method of treatment which permits beryllium-copper to be brazed with silver alloys that flow in the range of 1145 to 1200° F. with subsequent development of full hardness.

A. M. Setapen, manager, Engineering Div., and **W. D. Warren,** Metallurgist, are with Handy & Harman of New York and Bridgeport.

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The published curves on the effect of time and temperature on the heat treatment of beryllium-copper show that an increasing loss in hardness results from heating this material at temperatures above about 625° F. However, these curves show the effect of temperature on a scale of hours and do not clearly indicate the effect of short time heating. Since time is an important factor in both the solution treatment and in the precipitation hardening treatment it seemed entirely possible that parts of small section could be silver brazed at temperatures up to 1300° F. without seriously disturbing the precipitable phase if the heating for brazing were accomplished in a period of a very few minutes. Brazed assemblies could then be hardened by the normal aging treatment at 600° F.

For these tests, strip stock 0.010, 0.020 and 0.050 in. thick of the standard 2.0% beryllium-copper (0.2% Co) was obtained rolled 1 and 2 numbers hard after solution treatment.

Table 1 shows the hardness on the Rockwell 30N scale of this material as-received, and after aging for the recommended 2 hr. at 600° F. for maximum hardness and spring properties. These figures for aged stock agree well with the performance predicted by the supplier.

Table 1—Rockwell 30N Hardness

Thickness ⟶	*0.010 in.*	*0.020 in.*	*0.050 in.*
As-received	29	25	35
Aged 2 hr. at 600° F.	59	62	
As-received material annealed in Furnace operating at 1300° F. Time at Temp.			
1 min.	11	14	30
2 min.	10	12	25
5 min.	10	10	13

The effect of furnace annealing as-received material for 1, 2 and 5 min. at 1300° F. (Table 1) indicates that the 0.010 in. thick material is very considerably softened even in 1 min. The 0.050 in. thick material requires considerably more time at temperature to be softened to the same degree.

The effect of brazing on fully age-hardened beryl-

lium-copper was determined by obtaining 3-in. lengths of $^1/_2$-in. wide strips which were aged for 2 hr. at 600° F. to substantially the same Rockwell 30N hardnesses listed in Table 1. The ends of these strips were filed square and butt joints were torch brazed using a suitable flux and an alloy flowing at 1145° F.* Care was taken to concentrate the heat on the joint area and to conduct the heating and hand feeding of the brazing alloy as rapidly as possible. The brazed specimens were allowed to air cool. Rockwell 30N readings were taken at distances of $^1/_8$, $^1/_4$ and $^1/_2$ in. on each side of the brazed joint with results as shown in Table 2. It can be seen that a very considerable hardness loss has occurred near the joint but that the loss is small $^1/_2$ in. away from the joint. Thus it is seen that these brazing temperatures appear to effectively anneal the beryllium-copper. Some of these samples were then reaged at 600° F. for 1 hr. This resulted in a restoration of hardness, even $^1/_8$ in. from the joint, to values within a few points of the maximum aged hardness. Apparently, even though brazing decreases the hardness locally, it does not seriously reduce the amount of precipitable phase available for hardening on reaging.

* Handy & Harman's proprietary alloy Easy-Flo 45 and Handy Flux were used throughout these tests

Table 2—Rockwell 30N Hardness Values on Age Hardened Be-Cu Torch Brazed and Reaged 1 Hr. at 600° F.

Thickness→	*0.010 in.*		*0.020 in.*		*0.050 in.*	
Distance from joint, in.	*Brazed*	*Reaged*	*Brazed*	*Reaged*	*Brazed*	*Reaged*
$^1/_8$	19	48	24	59	36	58
$^1/_4$	29	55	33	58	40	57
$^1/_2$	56	58	58	61	53	58

Readings given are results of averaging six test pieces. These results confirm the belief that Beryllium-Copper has sufficient latitude so that short time reheating to brazing temperature of 1200–1300° F. does not seriously impair subsequent precipitation hardenability. They further suggest that a greater response to hardening should be obtained by performing the brazing on the

Beryllium-Copper. Magnification, 500 ×

Fig. 1

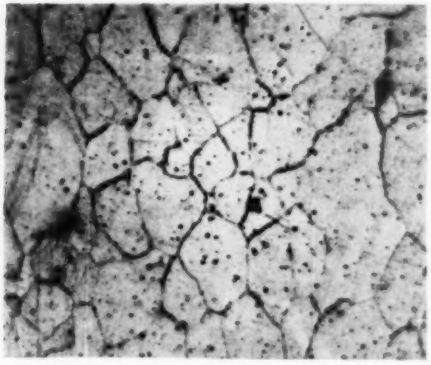

Fig. 2

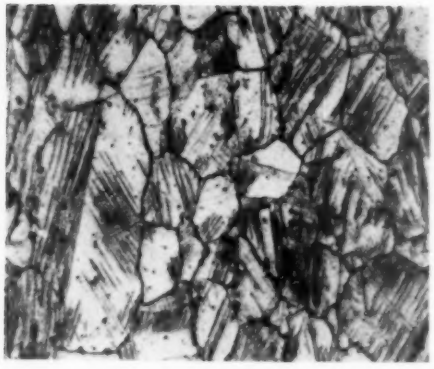

Fig. 3

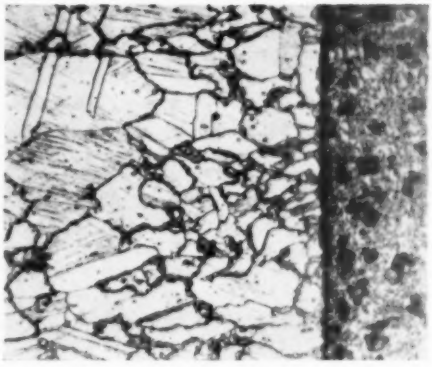

Fig. 4

Fig. 1 As-received. Solution treated and rolled 2 numbers hard
Fig. 2 Aged 2 hr. at 600° F. R_{30N} = 62
Fig. 3 Section $^1/_2$ in. from brazed joint. Aged 2 hr. at 600° F. R_{30N} = 61
Fig. 4 Section at brazed joint. Aged 2 hr. at 600° F. R_{30N} = 61

Table 3—Joints Torch Brazed on Material As-Received, Then Aged at 600° F.

Thickness →	*0.010 in.*		*0.020 in.*		*0.050 in.*	
Distance from joint, in.	*Brazed*	*Aged 1 hr.*	*Brazed*	*Aged 1 hr.*	*Brazed*	*Aged 1 hr.*
1/8	18	50	20	59	28	59
1/4	28	54	21	60	33	59
1/2	31	58	25	60	41	61
1	32	59	26	61	35	62
	Brazed	*Aged 2 hr.*	*Brazed*	*Aged 2 hr.*	*Brazed*	*Aged 2 hr.*
1/8	17	51	17	61	21	61
1/4	26	54	20	61	31	59
1/2	31	59	24	61	44	60
1	31	59	24	62	36	62
	Brazed	*Aged 3 hr.*	*Brazed*	*Aged 3 hr.*	*Brazed*	*Aged 3 hr.*
1/8	17	51	17	61	21	61
1/4	30	56	18	61	23	62
1/2	32	59	26	61	36	62
1	32	59	25	62	35	63

solution treated and cold worked (as received) material.

Therefore a similar group of samples was torch brazed on material in the as-received condition (i.e., solution treated and cold rolled, not age hardened). After brazing, these samples were aged at 600° F. for periods of 1, 2 and 3 hr. Rockwell 30N hardness readings were taken both before and after aging and are recorded in Table 3.

These results show that beryllium-copper 0.020 in. and thicker, which has been torch brazed with a low-temperature silver alloy, can be aged to full hardness in 1 hr. This hardness is obtainable immediately adjacent to the joint and longer aging times only increase the hardness by 1 or 2 points. The 0.010-in. thick specimens did not respond to full hardness near the joint indicating that the localized heating on this thin strip had noticeably affected the precipitable phase. Even here the hardness of aging after brazing was only 9 points below the maximum.

It should be emphasized that the heating period involved in brazing a joint was in all cases less than a minute and averaged about 15 sec.

A number of joints were furnace brazed using the same alloy and flux. In making these joints, the strips were held in position with a stainless steel spring on a thin graphite block that was recessed under the joint area. After positioning and fluxing the previously filed and emeried pieces, a 3/8-in. length of 0.045-in. diam. brazing wire was placed over the joint and the whole assembly placed just under the thermocouple in an electric furnace operating at 1300° F. The furnace required 3 min. to return to temperature and the total time in the furnace ranged from 4 to 5 min.

The hardness of the beryllium-copper after brazing was of the same order as that at the joint in torch brazing. The hardening response on aging, however, was less than in torch brazing and averaged 50–55 Rockwell 30N as compared to a potential full hardness of 60–61 which was obtained by torch brazing. This lack of complete hardness response undoubtedly reflects the effect of the increased time at brazing temperature in the furnace over that employed in torch brazing.

This loss of hardenability on furnace brazing, although considerable from the standpoint of maximum physical properties, may in many cases not be objectionable. Some users of beryllium-copper for spring members do not heat treat to obtain maximum properties but try to heat treat to a hardness approximating 40 Rockwell 30N so that the spring members may be adjusted in the field.

Figure 1 is a photomicrograph of the solution-treated and cold-rolled beryllium-copper as-received. It shows practically no Beta phase. The material in the wider grain boundaries is a beryllium-rich phase that has separated out of the solid solution. It represents a commercially attainable, although not quite perfect, solution-treated structure.

Figure 2 is the same material aged at 600° F. for 2 hr. It shows the characteristic stripping of the grains indicative of the ordering of the unresolvable Gamma precipitate on preferred crystallographic planes.

Figure 3 shows a section 1/2 in. away from a torch-brazed butt joint. This specimen had been aged at 600° F. for 2 hr. Its structure is very similar to that of Fig. 2 except that the more prominent striping is micrographic evidence of a close approach to maximum hardness. No appreciable grain boundary reaction has occurred.

Figure 4 is on the same specimen showing the area at the joint. It can be seen here that, immediately adjacent to the joint, the brazing heat has caused some recrystallization and some decomposition of the solid solution into copper-rich grains surrounded by a gray beryllium-rich phase. Although this decomposition represents a loss of beryllium available for hardening, the degree or extent of this loss is so localized that its effect on the hardenability is very slight. Many of the grains in the micrograph show the normal aged structure.

From the standpoint of the effect of silver alloy brazing on the hardenability of beryllium-copper it has been shown here that torch brazing with silver alloys flowing in the range of 1145–1200° F. can be performed and

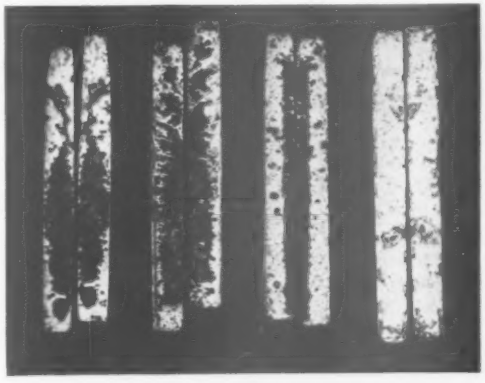

Fig. 5 Magnification, 3 ×

the brazed assemblies subsequently aged to full hardness. More care and skill are required of the operator when the material to be joined is below 0.020 in. thick and maximum hardening response is desired.

With suitable refinements of the heating and cooling cycle, furnace brazing can be performed without serious adverse effect on the hardenability.

Joint strengths up to 90,000 psi. (approximately the proportional limit of the beryllium-copper) have been obtained on brazed and age-hardened butt joints. To consistently obtain joints of this strength a considerable degree of skill and care is required. The principal cause of low joint strength is flux entrapped in the joint which reduces the joint area in proportion to the number and size of the flux pockets. There is also a very noticeable tendency for the alloy to appear to flow normally on the surface but on breaking the joint it is often found that the alloy has not flowed all the way through the joint. These defects are shown in the three joints in the left hand side of Fig. 5. The three joints illustrate the defects that are likely to be found due to inadequate heating. Dark areas are those coated with flux but not wet by the brazing alloy. The joint on the right contains but one flux cavity. Joint strength was 88,000 psi.

There are a number of factors that may operate to cause joint defects. Of these it is believed that the activity of the flux exerts the major influence. The flux used melts through a range of 1050 to 1100° F. and is completely fluid and active above 1100° F. Due to the refractory nature of beryllium oxide it is essential to use undiluted flux and some superheat above 1100° F. in order to get the maximum oxide solvency at the time the brazing alloy flows.

It was found that in order to get sound high strength joints by torch brazing it was necessary to heat the beryllium-copper to a temperature slightly higher than the flow point of the alloy before feeding the alloy into the joint. This slight overheating was necessary to promote adequate flux fluidity and activity due to the proximity of the liquidus points of the flux and the brazing alloy.

In furnace brazing the problem of flux entrapment and low joint strength is more acute than with torch brazing. This is especially true when the mass of jigs or fixtures holding parts to be brazed are large in relation to the parts being brazed. In furnace heating where the alloy is preplaced and directly exposed to radiant heat, there is an opportunity for the brazing alloy to melt and flow all around the surface of the joint before the flux in the joint has attained the desired amount of superheat. The flux entrapped by this action is not displaced by the alloy. In furnace brazing it is always desirable to have the brazing alloy concealed from the source of heat so that it is the last part of the assembly to come up to temperature. Then when it flows, the flux will have become active throughout the joint area and the flow of the alloy toward the source of heat will displace the flux and produce sound joints.

In conclusion it has been shown here the beryllium-copper has a sufficient latitude so that low-temperature silver alloy brazing involving temperatures up to 1250–1300° F. and short heating times can be performed without seriously affecting subsequent age hardenability.

It is true, however, that each industrial application will require some study and thought as to the exact method of heating to be used and a balancing of the method to be used against the desired physical properties.

We would like to thank the Beryllium Corp. for their cooperation in furnishing material for these tests.

New Factors to Be Considered in the Design and Welding of Ships

Discussion by David Arnott

I have noticed a tendency of late years to minimize the importance of our welded ship failures on the grounds that complete failures have also occurred to riveted ships in service and if we are going to solve our welding problems we have got to recognize all the facts. One important fact is that while some of our welded ship failures are very mysterious, riveted ship failures in the past could invariably be readily explained Either the scantlings were insufficient for the designed service to begin with or, through wastage, had deteriorated to an extent that the structure was incapable of standing up under an overload, a badly distributed load or abnormally severe weather and sea conditions. The *Oklahoma* and *Mielero* mentioned in the paper, for example, were both deficient in longitudinal strength as compared with the modern standards of the Classification Societies and the International Load Line Regulations, and in the light of our present knowledge it is not at all surprising that they should have failed in service. Our welded ship failures, including the plate fractures and partial failures of the structure which occurred in the Shipyards during construction, are much more difficult to explain. Never in the history of shipbuilding has a riveted ship experienced a complete structural failure, when lying at her builder's dock, when subjected only to a comparatively smooth water bending moment

David Arnott is a Consultant for the American Bureau of Shipping. Retired Vice-President and Chief Surveyor.

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as did the *Schenectady* and *Belle Isle*. It was the unprecedented nature of these and other spectacular casualties that was responsible for the appointment of Investigating Committees and the resulting initiation, both at home and abroad, of innumerable research projects some of which are still in hand.

It is obvious that design, workmanship and material must all be considered in investigating the cause of these failures. It is useless to speculate on which of these is the most important and for our purpose it is sufficient to consider them of equal importance. So far as the Liberty ship failures were concerned, poor design of hatch corners and other details was the obvious principal contributing factor, although it should be emphasized that we did have major failures in this class of ship which could not be attributed to unsuitable design details. The relative superiority of round as against square corner openings was fully recognized away back in the early days of riveted construction. Round corners and even round corner coamings as in the so-called Kennedy design were then common practice in way of hatches where the deck and hatch corners were supported by ordinary round pillars. When the solid round pillars were dispensed with and the deck was supported by deep girders in association with wide-spaced stanchions for greater ease in cargo handling and stowing, the longitudinal hatch coamings were made a part of the girder system and continued past the hatch corner in the form of a tapered bracket as shown in Fig. 4 of the paper. These extensions beyond the hatch corners were a nuisance and were later dispensed with when other methods of compensating for the abrupt discontinuity were found and had proved adequate in service.

Perhaps too much has been made of features like hatch corners and other details of our warbuilt Liberty ships, which experience has shown to be quite unsuitable for welded construction. Improved details, which have proved satisfactory in service, were embodied in the design of the Victory ships long before the De Garmo hatch corner experiments had been carried out. I am not belittling in any way the value of the De Garmo experiments as a research project. The point I wish to make is that design details do not provide the basic reason for the difference in behavior between the welded and the riveted ship so far as the incidence of cracking is concerned.

Investigations into the reasons for our tanker failures are much more important so far as providing a solution of the main problem is concerned. In the first place, a tanker is an extremely simple longitudinally framed box girder structure, where the single deck plating and the single bottom plating comprise the top and bottom flanges of the hull girder, with the shell sides and the twin longitudinal bulkheads acting as four vertical webs. Numerous transverse bulkheads keep the box section in shape and provide adequate resistance against racking stresses. The deck hatches are small circular openings and other design details are not so vulnerable to criticism as was the case in the Liberty ships. The scantlings of the T2 tankers are more than adequate on the basis of a comparison with the scantlings of riveted ships of similar dimensions and type which have proved satisfactory in service so far as structural integrity is concerned. It should be emphasized that the great majority of the T2 tankers built during the war have been structurally satisfactory in service, although any comparison is complicated by the fact that most of the tankers of this particular type have now been fitted with riveted longitudinal straps in accordance with the recommendations of the A.B.S. and the Coast Guard. The fact that a number of tankers much larger than the T2 type, which are completely welded with no riveted straps or other crack arrestors installed, have been in service for some years without experiencing any serious structural trouble is an interesting sidelight on the problem but does not make its solution much easier.

Mr. Forman is to be congratulated on an interesting paper which is well worthy of study by all who are interested in the design or construction of welded ships or other large structures.

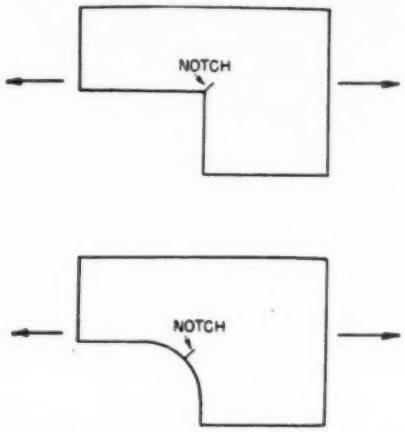
Author's Reply

The author is very appreciative of the discussion by Mr. Arnott. Mr. Arnott's contribution is particularly fruitful because he speaks not only from his many years' experience in the field, but also as one who has pioneered and encouraged the building of all-welded ships in the United States. We share the common aim of attempting to better understand the reasons for the ship failures. I am quite sure that a common solution will be nearer if we air our differences of opinion.

Mr. Arnott points out that there is a basic difference between the failures of welded and riveted ships. The author agrees that there is a difference in the behavior of riveted and welded structures and that any tendency to ignore this difference will lead to confusion. It is for this reason that the first section of the original paper emphasized that the conditions for the transmission of stresses in a riveted structure differ from those in a welded structure. It does not follow, however, that a riveted structure is therefore incapable of failure due to notch effects. Mr. Arnott's statement that the failures of the *Mielero* and *Oklahoma* were caused solely by insufficient longitudinal strength seems to oversimplify things a bit. It does not explain why these failures were brittle in character. Much more needs to be known about the behavior of riveted structures before a fully satisfactory explanation can be given.

Referring back to the difference in behavior between welded and riveted structures, it should also be recognized that any two dissimilar welded structures do not behave in the same manner either. The difference in the conditions for the transmission of stresses undoubtedly accounts for the major difference between the behavior of riveted and welded structures, because it directly affects the effectiveness of a notch. Two differently designed welded structures will also transmit the stresses in a different manner, and, as a result, the same notch will vary in effectiveness. Let us take two

specimens of flat plate and cut the first with a square corner and the second with a large radius (see Fig. 1). If we then introduce an identical notch in each specimen, would we not be safe in assuming that the effectiveness of the small notch would vary with the sharpness of the major discontinuity? In other words, the effectiveness of any particular notch is dependent on the pattern of stress flow in the structure.



This should lead us to the conclusion that the same hatch corner from the same steel would be more susceptible to failure in one type of ship than in another. The suitability of any other design detail would have to be evaluated in terms of the conditions for the transmission of stresses as determined by the over-all design. It is therefore the opinion of the author that a full understanding of the problem cannot be achieved by either the test results of small specimens or even the larger hatch-corner tests. More study is required of the behavior of various types of welded ships to determine what aspects of the over-all design are instrumental in affecting local details. This type of study will help to explain why the larger tankers, the C-3 and C-1 Cargo Ships, did not show major failures despite the fact that the same steel and the same type of design notches were incorporated in all of them.

The foregoing remarks are not meant to minimize the importance of improved details of design. It has already been shown that the introduction of these improved details reduced the incidence of fracture from 1% to 3%.

It is the contention of some people that since a welded structure is monolithic, it is impossible to build one which can develop conditions for stress transmission to make it as unsusceptible to notches as riveted structures. The author believes that the DeGarmo hatch-corner tests and other tests evaluating design details are important because they lay a basis to refute this contention. Experience with the ideal Kennedy design has shown that it is possible to design a severe structural discontinuity to behave in a completely ductile manner. It is not stretching our imagination too far to assume that, even if a notch did exist in the welded butt joints which are now removed from the radius of the corner itself, it would not change the test results appreciably. We actually do not know that this notch did not exist. Referring back to the box girder tests mentioned in the paper, we do know that a lack of fusion in the butt-welded tension plate had little effect on the test results of Box Girder No. 1.

Mr. Arnott states that the plate fractures which occur during construction are much more difficult to explain than those occurring in service. The author was rather active in a large shipyard during the war and has in his possession complete reports of all fractures of this kind which occurred over a period of two years. A close examination of these case histories forces him to the conclusion that it is much easier to explain construction cracks than the splitting in two of ships such as the *Schenectady*. It is relatively easy to determine the source of energy and the local notch effect which caused the construction fracture. The success of such analyses is attested by the record of this particular shipyard, where the establishment of rigid control over shipfitting and welding practices reduced these fractures from 33 to 2 for equal periods of time.

Mr. Arnott also tends to make a special case of the failure of tankers because they do not contain the standard hatch corners. It is true that the absence of large hatches eliminated the hatch-corner problem. However, a review of the design of these vessels shows that other deficient design details were the source of the failures. The final report of the Board of Investigation on the "Design and Methods of Construction of Welded Steel Merchant Vessels" states that design discontinuities were the source of these fractures and that improved details have already been found to mitigate these notch effects.

The author wishes to thank Mr. Arnott again for his thought-provoking and constructive discussion.

Resistance Welding of Jet Engines

The application of spot, stitch and seam welding to jet engines is described. Early experiences are reviewed leading up to present-day applications and techniques

by H. E. Lardge

INTRODUCTION

ONE of the foremost engineering developments of the present time is that of the gas turbine engine for aircraft propulsion and it is perhaps not generally realized how important a part resistance welding plays in the manufacture of such engines. One of the advantages of the turbine engine, as originally conceived, was that it was lighter in weight than a normal reciprocating engine of equivalent output. This result was obtained, in part, by the use of sheet metal for the construction of certain main sections of the engine (such as the combustion and exhaust systems) and the resistance welding processes of spot, stitch and seam welding are extensively used in this new field of engineering construction.

In order to appreciate the conditions under which parts and assemblies fabricated by such means must operate, it is necessary briefly to explain the working of the jet engine, which is comprised of four main items, namely:

1. The centrifugal compressor
2. The combustion system
3. The turbine
4. The exhaust system

Air from the high-speed compressor is led to the combustion chambers where a continuous supply of atomized liquid fuel is burnt. The resultant gases of combustion, now at high velocity, pass to the turbine (which drives the compressor) and then through the exhaust unit and jet pipe to atmosphere emerging in the form of a high velocity jet. From this it will be understood that the operating temperatures of the parts comprising the combustion chambers and the exhaust system (with which we are concerned) are high and entail the use of special heat-resistant alloys. In addition, high dynamic stresses are imparted to these components by high-frequency pulsations of considerable magnitude present in the air stream. It will, therefore, be appreciated that the application of the resistance welding processes to the manufacture of such assemblies was not accomplished without some difficulty.

On the original Whittle design resistance welding was not used to any great extent, but when the production of jet engines in quantity was envisaged it was obvious that resistance welding, and seam welding in particular, had many advantages to offer in the way of rapid and efficient production when once the difficulties inseparable from such an application had been overcome. This, at any rate, was the opinion of the engineers of the firm of Joseph Lucas Ltd., Birmingham, who were invited to collaborate with engine firms concerned with the development and manufacture of jet engines for the British Government, and subsequent experience has proved this view to be correct.

EARLY DEVELOPMENTS AND EXPERIENCES

There are two main types of jet engines, namely the "reverse flow" and the "direct flow" types. Early engines were of the "reverse flow" pattern and Fig. 1 is a diagrammatic view of the Power Jets W.2.B. design, later to be developed into the Rolls Royce "Welland." On this engine the combustion chambers, 10 in number, are cylindrical in form and are grouped around and parallel to the main axis of the engine. Each chamber consists of an outer, or air casing, and an inner member, or flame tube, inside which combustion takes place. The air casings operate at comparatively low temperatures and are joined together by interconnectors for pressure equalization to form one assembly (Fig. 2).

The casings were originally made from 18–8 stainless steel sheet (0.0164 in. thick) for purposes of resistance to corrosion. Each casing was made by "wrapping" and then longitudinally stitch welding along a narrow overlap, leaving the welded region similar in thickness to the metal. On engine tests, catastrophic fatigue failures were experienced along the longitudinal welds. Seam welding on a wider overlap was introduced, with some improvement in results, but the failures still persisted, sometimes after only a few minutes running.

An oscillographic check revealed high-frequency pulsations in the air stream which were inducing high dynamic stresses at the notch along the weld, thus allowing the fatigue strength of the metal to be exceeded locally

H. E. Lardge is with Joseph Lucas Gas Turbine Equipment Ltd., Burnley and Birmingham, England.

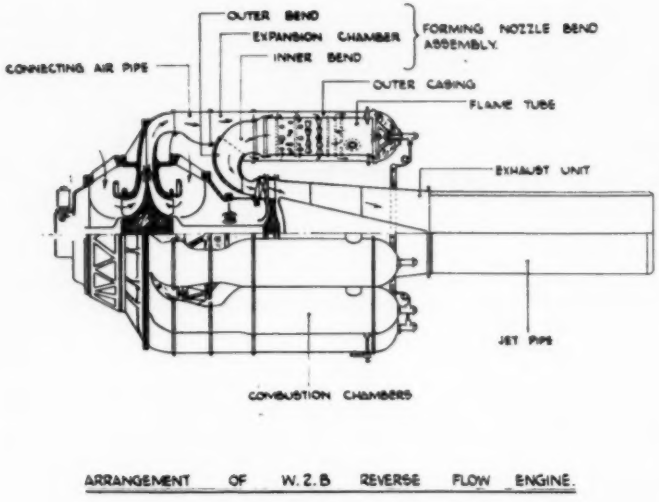


Fig. 1 Diagrammatic view of W.2.B. "reverse flow" engine

The discharge nozzle assembly, which forms one of the major units of the engine, provides a good example of the marrying of resistance and fusion welding (Fig. 6). This assembly, part of whose purpose it is to lead the combustion gases to the turbine, is made from resistance-welded stainless steel pressings and solid flanges machined from centrifugally spun austenitic steel cylinders. The expansion chambers, 10 in number, are made by stitch and seam welding half pressings together and these in turn are fusion welded to outer bends. The whole assembly is built up in a welding fixture or manipulator and fusion welded together. The inner bends, which actually lead the gases to the turbine entry, are made from parts of thin Inconel sheet, stitch and seam welded together.

and resulting in such typical failures as shown in Fig. 3. A change of material to mild steel overcame this difficulty and is accounted for by the higher internal damping capacity of this material allowing the energy loss to be more generally absorbed in the casing. Protection from corrosion is given by aluminium sprayed coatings.

The flame tubes (Fig. 4) are made from a specially developed sheet material called Nimonic 75, basically an 80–20 nickel chromium heat resistant alloy with high mechanical and fatigue strengths at elevated temperatures. The flame tube is made by wrapping and longitudinal seam welding, the strengthening bands being circumferentially welded to the flame tube. The stub pipes, 16 per flame tube, are spot welded in position and the flame tube head (Fig. 5), which is of pressings of stainless steel and Nimonic 75, is also constructed by spot welding.

Fig. 3 Fatigue failure at seam weld

Fig. 2 Air casing assembly

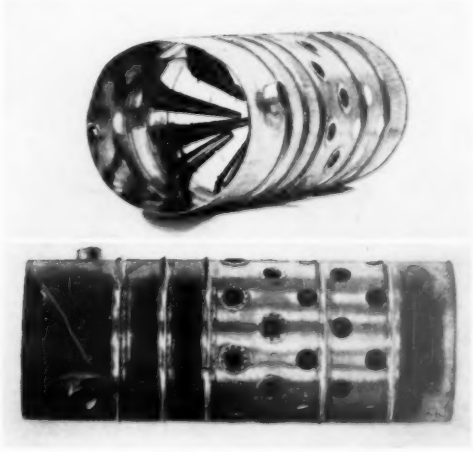


Fig. 4 Flame tubes

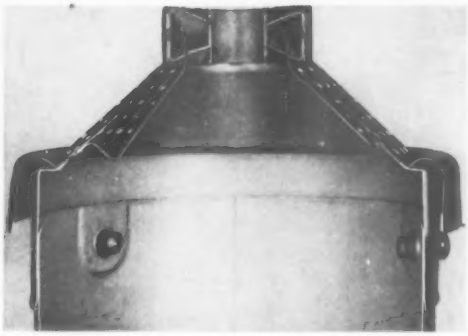


Fig. 5 Flame tube head

Fig. 6 Discharge nozzle assembly

LATER ENGINES

As the exhaust units and jet pipes of either the "reverse flow" or "direct flow" types of engine are very similar in construction, it is proposed at this stage to say something about the manufacture of combustion chambers for some of the "direct flow" engines and a diagrammatic view of this kind of design, as exemplified by the Rolls Royce Derwent I engine, is shown in Fig. 7.

The air casing (Fig. 8) is of combined cylindrical and conical form and is again constructed from mild steel sheet by wrapping and seam welding. The stainless steel interconnector parts are stitch welded to the body prior to it being sprayed with aluminum. The sealing ring at the small end of the casing is of heat-resistant alloy and is seam welded to the mild steel body. The expansion chamber, which is shown bolted to the casing, is made from two odd-shaped half pressings of mild steel stitch welded together, the pressed end flanges being attached by the same process. The flame tube assembly (Fig. 9) is fabricated throughout by resistance welding and, with the exception of the outer pressing of the flame tube head, the whole assembly is made from Nimonic 75.

The flame tube for the very successful Rolls Royce Derwent V engine, also of the "direct flow" type, is made throughout of Nimonic 75, as several fatigue fail-

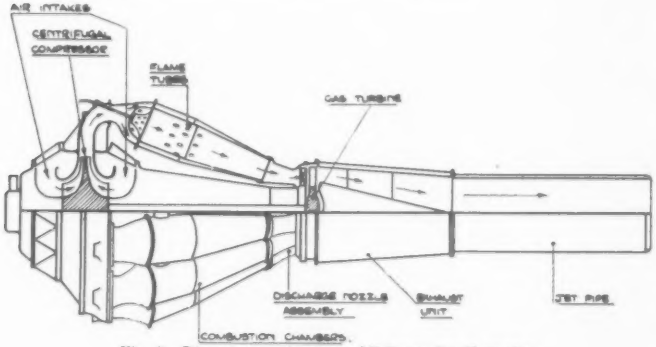


Fig. 7 Diagrammatic view of "direct flow" engine

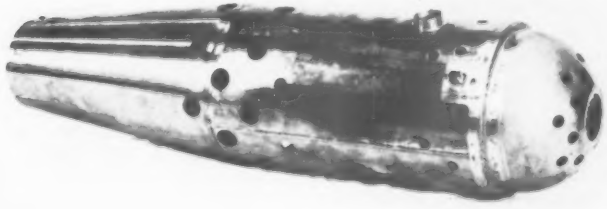


Fig. 9 Flame tube assembly

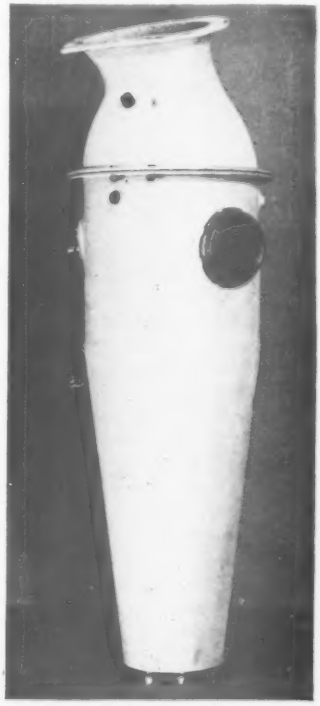


Fig. 8 Air casing and expansion chamber

ures had been experienced on the stainless steel part of the Derwent I flame tube head. This flame tube (Fig. 10) provides an excellent example of the application of resistance welding to a dynamically loaded structure of unusual design and material. The construction of the air casing (Fig. 11) follows similar lines to those already dealt with and it is not proposed to go into detail about this.

Fig. 10 Derwent V flame tube assembly

EXHAUST UNIT AND JET PIPE MANUFACTURE

A typical exhaust unit for this type of jet engine is shown in Fig. 12. This asembly is located immediately behind the turbine and is very interesting from a resistance welding viewpoint. The truncated outer cone of stainless steel is longitudinally seam welded and is tack spot welded to the solid flanges at each end in a fixture with internal expanding electrodes (Fig. 13) prior to the flanges being seam welded. The spacing bands are then seam welded to the outside of the cone, provision having to be made for distortion by leaving some machining allowance on the flanges.

The inner cone, whose purpose it is to streamline the gas flow behind the turbine disk, is also made from stainless sheet seam welded as far down as practicable, the remainder of the overlap being stitch welded and a machined tip is then stitch welded into the end to complete the conical form. A stiffening cone for carrying the cross-support bearings is spot welded inside the inner cone and a machined flange is stitch welded to the open end.

The cross tubes, which support the inner cone, have to be shielded from the gas stream to avoid losses due to turbulence and this is done by four fairings which cover the tubes in the annular space between the inner and outer cone. These fairings are made by spot welding an outer skin of Nimonic 75 to four stainless steel spacers (Fig. 14).

The last assembly to be described is the jet pipe (Fig. 15). This is made by joining a number of seam-welded sections of stainless steel to form a cylinder of the desired length. Spacing bands, similar to those on the exhaust unit outer cone, are seam welded to this cylinder which is then covered with heat insulation, the whole being finally enclosed with sheet aluminium covers. It will be seen that seam welding provides an ideal way of building the inner member of such a unit.

Fig. 11 Air casing

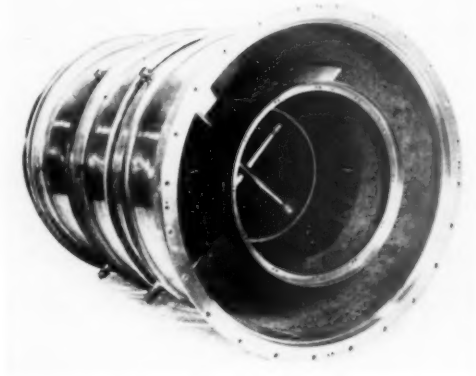


Fig. 12 Exhaust unit, part-finished assembly

MATERIALS, PLANT AND TECHNICAL CONTROL

This paper would be incomplete without some remarks on the materials used and the table, Fig. 16, gives some of the properties of these alloys as they affect resistance welding. The oxide film present on the nickel-chromium alloys can be very troublesome and strict measures have to be taken to remove any oxides after heat treatment, prior to welding. The high elec-

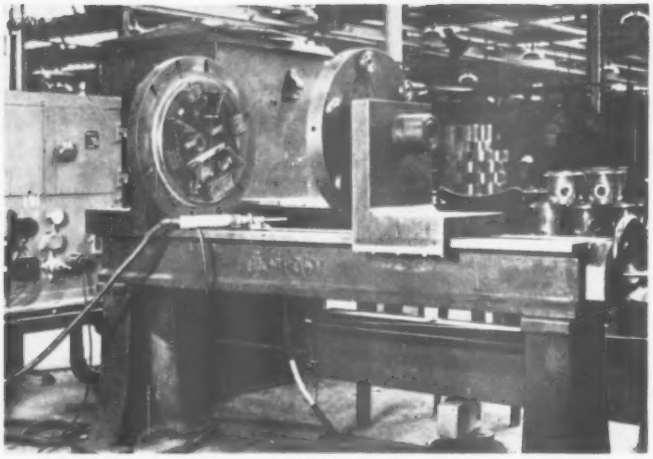


Fig. 13 Tack spot-welding fixture for outer cone

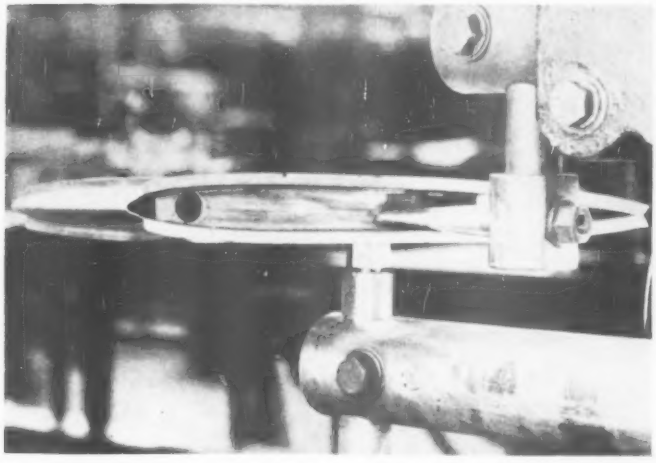


Fig. 14 Spot welding of fairing skin to spacer

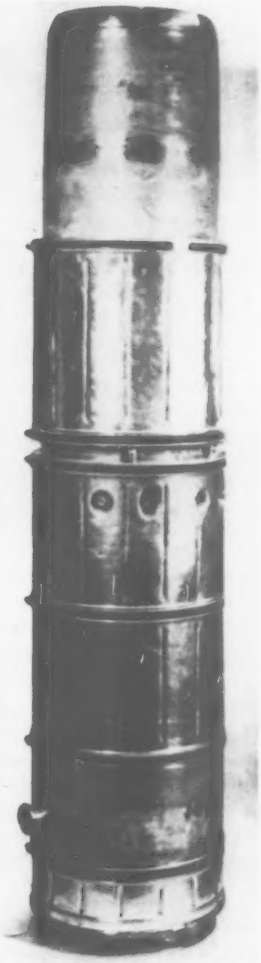


Fig. 15 Jet pipe assembly

Physical and Mechanical Properties of Materials, Fully Annealed, Which Affect Welding

Material	*Specification*	*Melting point, ° C*	*Specific resistance, microhms/-cm. cube (15° C.)*	*% conductivity of copper*	*Thermal conductivity, G.G.S. units at 15° C.*	*Coefficient of expansion*	*Ultimate tensile strength, tons/-sq. in.*	*Brinell hardness*
Mild steel	0.1–0.15% carbon	1450	11.5	15	0.14	0.000012	20–25	90–110
Austenitic 18–8 stainless steel	18% chromium, 8% nickel, titanium or other elements present	1450	73	2.36	0.038	0.000018	35–45	160–200
Inconel	80% nickel, 14% chromium and 6% iron	1395	98	1.76	0.036	0.000014	35–42	140–180
Nimonic 75, 80–20 nickel-chromium alloy	80% nickel, 20% chromium and some titanium	1375	110	1.57	0.030	0.000015	42–50	160–200
H. R. Crown Max. centl. casting	23% chromium, 1% Si, 12% nickel and 3% tungsten	1410	87	1.98	0.030	0.000017	40–45	200–230

Fig. 16 Table of properties of materials

trical resistivity of these alloys also has to be catered for, particularly when seam welding the thicker gages. Another important point is the high coefficient of expansion which can give rise to considerable distortion when seam welding. Fortunately, all the alloys being corrosion resistant, they can be welded under water and advantage is taken of this when stitch or seam welding by directing a flow of water over the electrodes and the work, thereby reducing distortion and minimizing electrode pickup.

With regard to welding plant, all the welding machines in use are of the straight alternating-current transformer type and all are fitted with weld-time control. For tacking spot welds prior to stitch or seam welding it is only necessary that the spot weld should be strong enough to withstand the stresses set up during the subsequent welding operation. Foot-operated machines are used as being convenient in operation. Where the spot welds are structurally loaded, fully automatic air-operated machines are used. For stitch welding, mechanically operated machines are in general use, all being equipped with full electronic tube controllers, with phase-shift heat control. Naturally, all the seam-welding machines are fully electronically controlled and those machines on which the most critical welds are made are fitted with the latest constant current control which can take care of considerable fluctuations of voltage in the main lines.

The question of welding technical control is a vital one in view of the fact that a faulty weld might give rise to serious trouble on an engine and a careful check is kept on all the resistance-welding processes in use. This is done by presenting initial test pieces, conforming as near as possible to the weld in question, to the metallurgical laboratory for approval. This check generally takes the form of a radiographic examination for weld continuity and porosity, a tensile test for weld strength and a metallographic examination for fusion and metallurgical structure. All the necessary data is logged and, when approved, a weld instruction sheet is issued carrying all the relevant technical data such as machine called for, electrode thrust, weld time, primary current and transformer tapping, etc. Thereafter, tensile-test pieces have to be prepared prior to any particular weld being undertaken and these test pieces have to break above a given load as stipulated on the instruction sheet.

It is, unfortunately, not possible to cover the subject of welding technique, but it will be realized that a considerable amount of pioneer work had to be undertaken before satisfactory results were obtained. As time went on, experience showed that some of the more difficult welds could be eliminated by changes of design and the examples given show how an intelligent grasp of the fundamentals required for resistance-welding construction by the designers can result in a practical production job of what might otherwise have been a difficult project to make.

ACKNOWLEDGMENTS

Cordial acknowledgments are made to Rolls Royce Ltd., Derby, England, for the particulars of their world-famous engines: to Joseph Lucas Ltd., Birmingham and Burnley, for facilities to prepare the paper and to the Ministry of Supply for permission to publish the information contained therein.

Proprietary materials mentioned in the table of materials are: H. R. Crown Max, Firth-Vickers Stainless Steel Ltd., Sheffield, England; Inconel, Henry Wiggin & Co. Ltd., Birmingham, England; and Nimonic 75, Henry Wiggin & Co. Ltd., Birmingham, England.

Resistance Welding Developments

Two new resistance welding developments are described and at the same time the underlying engineering principles leading to these developments are traced

by F. L. Brandt

WE have two new resistance welding machine developments that are of current interest to welding engineers: (1) Synchromatic flash welder and (2) three-phase power converter controlled spot, projection and seam welders.

F. L. Brandt is Asst. Sales Manager, Thomson Electric Welder Co., Lynn, Mass.

This paper was presented before the Philadelphia Section, A.W.S. at the November meeting.

Let us first consider flash butt-welding equipment For a little background and for comparison sake, we shall first consider conventional equipment.

1. Simplest, oldest universal welder with hand clamps and hand pushup device. This is a most universal machine because:

(*a*) The machine may be used to heat work by clamping the work in current carrying jaws and applying a suitable electrical current. This heating may be used merely for metallurgical reasons or when the work is hot, it

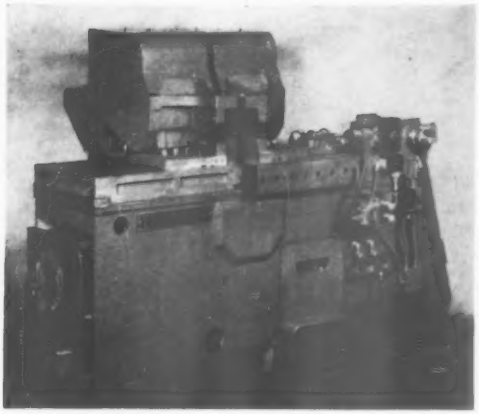


Fig. 1 RWMA size F3 synchromatic flash welder with guards removed

may be removed for subsequent bending or forming. The work may remain in the machine while force is applied longitudinally with the work axis by the pushup device to effect a forging or upsetting action. In practice, this machine action is widely used to upset valve stems. Conversely, while the work is hot, the pushup device may be operated in reverse to pull the work apart. For example, diamond shaped bars are pulled to form harrow teeth. In much the same manner, stranded steel cables are burned in two and all the individual strands are welded together simultaneously. If the machine is to be used on production heating-forging-pulling operations, output may be increased by providing an air cylinder pushup device or for heavy work a hydraulic pushup device.

(*b*) Butt welds may be made such as manufacture of chain links. The work ends are brought together under force and then heated by passage of electric current. When the work is hot enough, the current is cut off and the ends forged together. This butt welding is accomplished by one steady force.

(*c*) In order to speed up the process and in many cases, such as the manufacture of drills, reamers and the like, the flashing technique is used. We say technique, because the machine is not changed—only the method of welding is changed. In flash welding, the welding voltage is impressed on the workpieces. Subsequently, on contact, a flash occurs such as in any loose electrical contact. The flash burns and throws out particles of the workpieces. This flashing action is maintained by progressively advancing one workpiece toward the other until a high temperature is reached in the work, at which time the current is cut off and the work is forged together. Oversize work may be joined by preheating the work pieces outside the welder or better still, right in the welder by butting the work ends and applying the current in pulses and then proceeding with the flashing technique. This flashing technique embodies two distinctly different actions—flashing and upsetting.

2. The earliest development to speed up production flash welding was a motor driven cam operated pushup device. Obviously, the range of this machine is limited due to the fact that the shape of cam is not adjustable for various welding job requirements. Also, a high power level is required to insure sufficient heating in shortened flashing time. This system is still used most extensively for production applications.

3. The fully hydraulic flash welder was developed to give maximum adjustability, high production and means of getting high upsetting forces with versatility.

All of these flash welding machines embody the two distinct actions—flashing and upsetting.

(*a*) Hand—slow progressive, pull upset

(*b*) Motor—Cam flash—cam insert bump upset

(*c*) Hydraulic—metering or feed flashing valve—dump or equivalent upset.

The fully hydraulic flash welder is a most universal machine but its complicated multiplicity of components and adjustments gave impetus to development that gave birth to the Synchromatic.

The synchromatic pushup device is a simplified automatic or semiautomatic mechanism. Fundamentally, it is an air cylinder motion with a hydraulic snubbing device which provides infinitely adjustable speed through flow valve (range of 25 to 1). As mentioned before, conventional butt-flash welders embody two actions—flashing and upsetting. The Synchromatic permits these two actions in one device. The snubbing is designed to give an adjustable flashing acceleration and when the snubbing is released, a cushioned upsetting or forging is accomplished. This is a smooth over-all action with no hesitation going into the forging. We have found this control to be more uniform than any we have been able to machine in a rotating or flat cam device. For example, we are able to maintain flashing action on $^{3}/_{8}$-in. diameter aluminum rod for a period of 15 seconds and consume only $^{5}/_{16}$ in. of the $^{3}/_{8}$-in. diameter rod. As further testimony we are able to flash weld copper. The combination of improved flashing action and means of transition to forging permits a lower welding voltage than conventional equipment. This explains the reduced power demands and the ability to weld heavier work sections than previously. This reduction in machine size for a given maximum job reduces the inertia and friction of moving parts, and, thereby, permits lower unit upset forces. Our investigations are still going on and we are not ready to publish complete ranges of recom-

mended kva. ratings and upset forces. The simplified Synchromatic control will permit all or any of the operations that can be accomplished on a hand, a motor or a hydraulic device. The standard machine is operated through a four way manual valve with center position. Throwing the valve one way gives a completely automatic flashing and upsetting operation. Throwing the valve in center stops all motion. Reversing the valve returns the movable platen to start position. With this combination, the work may be preheated or postheated and the flashing action may be gradually initiated as in manual machines, so that "one of a kind" jobs may be welded. An experienced man reports that there need be no spoiled work. If the action is not satisfactory, the operation can be stopped for adjustment of voltage, platen opening or the like and then welding resumed. In fact, if the flashing rate appears fast or slow during the actual welding, the flow control valve may be adjusted to correct without interrupting the operation.

By simple addition of solenoid air valves for manual valves, a pressure switch and delay relay, the complete welding operation including work release and platen return can be made automatic. This means a single push button for complete operation, including clamping. The workpieces are placed in the welder and the button pressed momentarily. The operator picks up two more workpieces just in time to remove the completed weld.

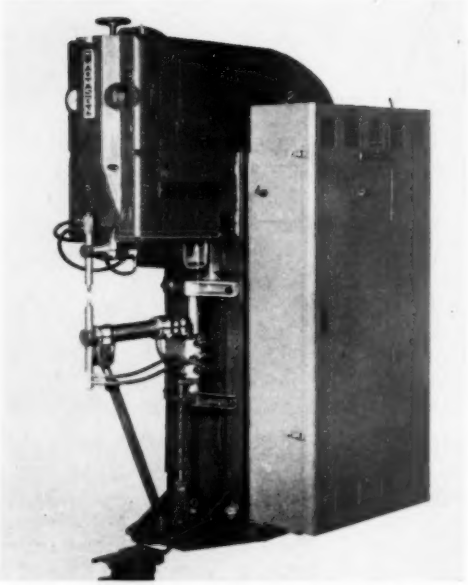


Fig. 2 Light duty press type spot welder with low frequency three phase converter control

THREE PHASE POWER CONVERTERS

We started development work on three-phase loading of resistance welders just before the last war. This work consisted of exploration of wet battery, dry disk rectifier and electronic tube converter. This work was discontinued for the duration but has been resumed. The dry rectifier work is still progressing in the laboratory, but we have been applying three-phase electronic rectifiers for nearly a year. During this period we have had a complete machine and converter for daily use in welding customer samples in our laboratory. This equipment has continually been open to anyone for demonstration. We have spot welded mild and stainless steel from two pieces 0.015 in. to two pieces $^1/_4$ in., aluminum up to two pieces $^1/_8$ in. and also yellow metals. We have found the converter particularly adaptable to heavy spot and projection welding.

We call the welding machine and control—A Three-Phase Welder. We call the electronic control a low frequency converter. The welding machine is conventional except the welding transformer. The converter is the latest accomplishment of the Ignitron tube—for without the Ignitron, the converter would not be possible. The Ignitrons are controlled by associated electronic equipment so that $^1/_2$ cycle of each of the three phases of the 60-cycle power supply are permitted to carry current in rapid succession. Each phase is connected electrically to a separate primary of the welding transformer. When this phase rotation is repeated and reversed and repeated twice again, a simulated 12-cycle current flows in the secondary of the welding machine. This is the standard method of supplying equipment, but equipment can be supplied to give any of a great number of frequencies, wave forms or impulse currents. For example, if the polarity is reversed after each rotation of $^1/_2$ cycle from each of the three phases of the power supply, a frequency of 20 cycles results. Here, again, the simulated frequency will vary depending on the zero gap or cool time between half cycle impulses.

This low frequency approaches direct current and greatly reduces inductive reactance in the secondary circuit of the welder. The secondary current output of the welder depends very much less than 60-cycle conventional equipment does on throat dimensions or the presence of magnetic material in the field. We have not found an application that would require a current compensator. As heavy steel sheets enter the throat of the welder, consistent welding is assured. Since the reactance is reduced, the equipment will be more resistance sensitive. This helps in the welding of heavy steel sheets because the welding current is determined by the resistances of the work and interfaces. As more and more shunting welds are made, the resistance of the circuit goes down and demands additional current and is thereby, somewhat self-compensating. In 60-cycle equipment, the inductive reactance chokes and limits the flow of current.

The converter consists of three Ignitron contactors (6 tubes) and all of the familiar elements of synchro-

nous control, that is, synchronous firing circuit, heat control circuit and sequence circuit. Conventional standard Ignitron tubes are used on 220–440 v., 60-cycle circuits. With exception of "B" size Ignitrons, rectifier type Ignitrons are required on 550 v. applications, at extra cost. Fifty-cycle equipment is ready for quotation. Twenty-five-cycle equipment is less needed and has less application and is not in sight. The power factor on the lines is in the vicinity of 80%. The installation of one spot, projection or seam welder on an isolated line is much more practical with three phase than single phase. The demand is reduced and the power factor increased. The demand reduction depends on the throat of the single-phase welder equivalent and the work to be welded. In general, 24–30 in. throat welders have a ratio of rating or demand of 2 to 1. This reduction in demand and increase in power factor reduces voltage regulation more than expected. For example, we have a single phase and a three-phase welder on the same power supply in our laboratory welding $^1/_8$-in. steel. We measure 4% drop single phase as compared to $^1/_2$% drop three phase. If you are acquainted with conventional 60-cycle single-phase equipment you have a new experience coming. The low frequency eliminates the surge and the heat fairly sneaks into the work. It is this low rate of rise of welding current that reduces the intense heat between electrodes and work and permits many more welds in aluminum between tip cleaning.

If you have ample power supply or operate many welding machines, the three-phase welder may not be attractive. In all such cases, a study must be made.

Production Tooling for Automatic Welding

Various types of automatic production welding machines are described, the advantages indicated, and qualifications of the designer of automatic machines are briefly touched upon

by Cecil C. Peck

THE submerged arc process of automatic welding is much faster than any arc-welding process known today. With this in mind, the prime consideration in the design and building of tools to assemble and weld parts is rapid handling and high arc time. The advances made in the art of machine welding make it possible to weld at speeds which for physical reasons cannot be reached or maintained by hand. In the older arc-welding process, the actual speed of welding was so little higher than that which could be obtained by hand welding that it seemed inadvisable to build efficient tools to apply the arc-welding process.

Another item which is of prime consideration and has always been troublesome in any arc-welding process is the necessity of cleaning the weld to remove the spatter. With the submerged arc process, the necessity for cleaning after the welding is practically eliminated.

With the submerged arc process, it is possible to use higher currents than is practical for handwork. It is also possible to weld with machine-like precision, holding the speed, current and voltage at very close ranges. When this is done, the quality of the weld is very excellent. Mechanized arc welding is possible by combining electric devices, hydraulic and pneumatic movement and other mechanical motions in the design of production tools; hence, operations are reduced to a minimum and the man's whole time is in the actual production of the parts instead of doing something over and over again on each part welded. With the use of these various mechanical movements, we have been able to secure quality work.

Properly designed production tools for welding should be made to take care of the handling of the parts so that the operator is not required to lift heavy parts or move

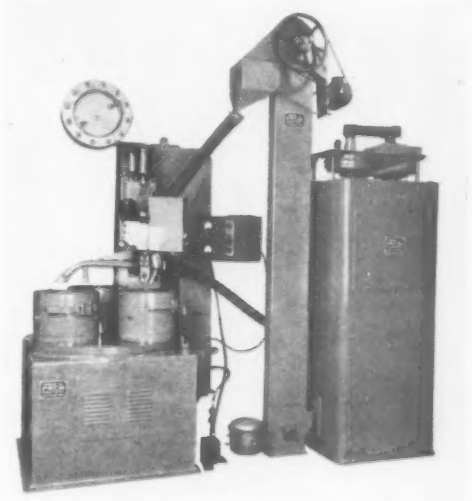


Fig. 1 A vertical turret type machine with built-in flux handling. The parts are loaded in it at one station, rotated to the weld station and then to the cleaning station. The parts are loaded, welded and cleaned in that order

Cecil C. Peck is President of the Cecil C. Peck Co., Cleveland, Ohio.

This paper was presented at the Twenty-Ninth Annual Meeting, A.W.S., Philadelphia, Pa., week of Oct. 24, 1948.

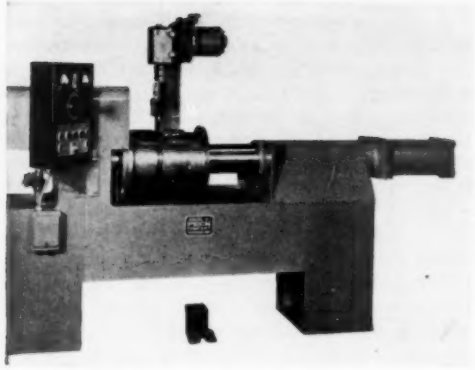


Fig. 2 "Load and Fire" using heavy coated wire. Heavy air cylinders grip the parts firmly while geared head and tail stock keep the parts in alignment during welding

light parts that can be conveyor handled. Well-designed tools will keep the arc time high and the out time low, thus making them more profitable for the manufacturer.

Long periods of training are not required for the operators of these machines, as any person of ordinary intelligence can learn to operate them in a short time.

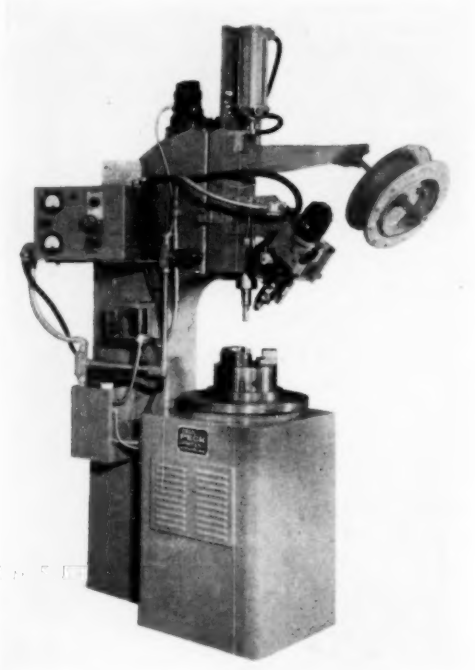


Fig. 3 Single operation vertical tool with fully automatic operation. The operator merely puts a piece in place, pushes a button to start all operations and removes the part when it is finished

The appearance of the automatic welding machines gradually are emerging from poorly designed gadgets to machines which will take their place with any other machine tools. It is nothing unusual to go into a large plant and see a contrivance, made of angles and "what not," welding parts for a machine selling for $100,000. This contrivance is usually a time waster.

The term "Automatic Welding Machine" is somewhat abused. After observing the automatic heads on the market in operation, one would probably discover that there are several handles that have to be pulled or knobs turned to start the weld. The designer of the

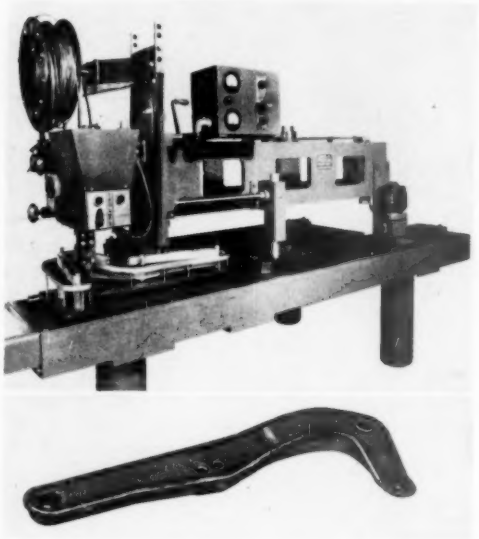


Fig. 4 This machine was designed to weld an irregular shape with different elevations. The part is shown in Fig. 4 (A) below

tools for automatic welding should take this into account and do these operations with electrical or other automatic devices.

There are two principal classes of work that can be welded with mechanical welding. The first is high production where one machine is set up and goes day in and day out on one piece. The second type is termed limited production where smaller numbers are made at one time, but there is not enough work to keep a special tool in continuous operation. Many of these products run into large numbers over a year's time. The problem is to design equipment that can be arranged for several different jobs to keep the machine in operation full time. The study of products often reveals that many miles of welds are to be made during a year's time.

Another problem in the design of tools for production welding is the preparation of the parts to be welded. Many jobs have high welding time due to the fact that preparation of the component parts has not been done with good tools, and many manufacturers expect the welding machine to take care of these wide variations.

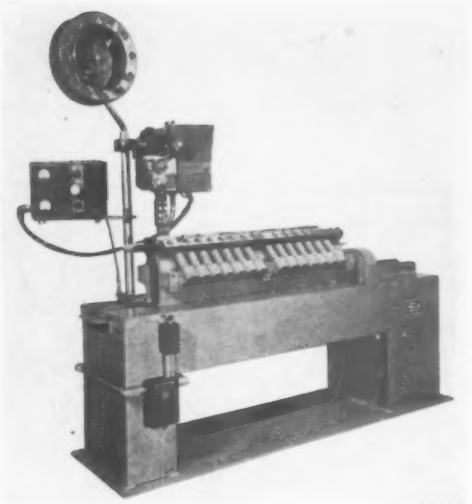


Fig. 5 A machine of the continuous welder type where the parts are passed through under the arc with three sets of feed rolls

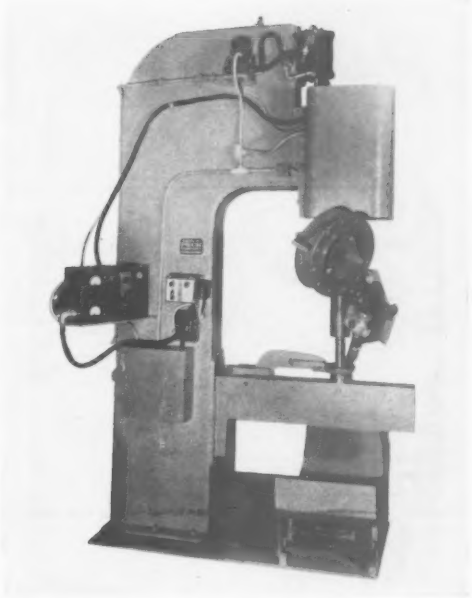


Fig. 6 In this design the welding head rotates and the part stays still. It is useful when welding spuds or parts that cannot be easily rotated. This is fully automatic in operation. The operator merely puts the parts in place, pushes a button and the parts are clamped into position. All operations are in succession

Many welding machines have been designed to first assemble the parts and then weld them together. It is our experience that the assembly and weld combinations do not work together. At any rate, the arc is idle while the assembling is going on. It has also been our experience that consultation with the manufacturer during the designing of the product is very valuable to him and enables us to obtain a design that is good from a welding standpoint.

There are several qualifications of the designer of tools for welding, and some of them are as follows: He should be a welding operator. We do not see how a man totally unfamiliar with welding can be intelligent in the design of tools for this purpose. He should know his electricity. Being familiar with motors, contactors, welding generators, and the like is very necessary. He should know how to apply hydraulic and pneumatic applications. He should know his materials handling. Poor handling makes any of these machines very inefficient. He should have some practical experience in machine tool design, and then, in addition, he should be a mechanic.

Some of the advantages of submerged arc welding can be described as follows: Production tools for submerged arc welding can be placed in machine production lines and adjacent to punch presses and machine tools. It is not necessary to have special ventilation nor is it necessary to have special rooms about it. The operator is not required to wear special clothing nor is he exposed to high heat from the arc. Arc burn is not a major problem with this process.

PRACTICAL WELDER AND DESIGNER

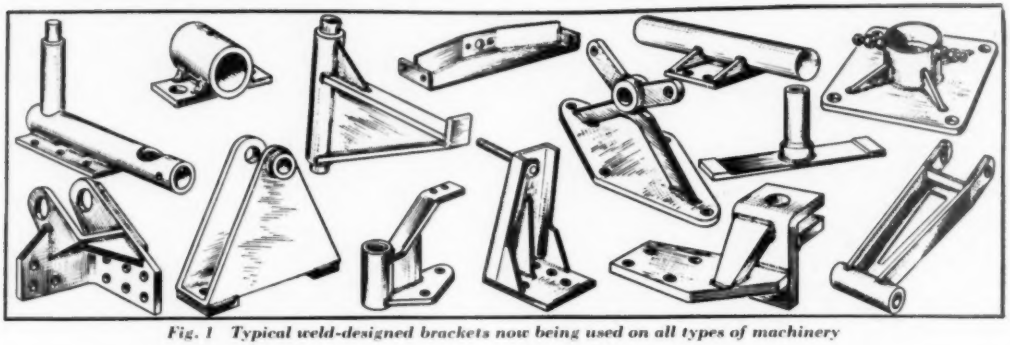


Fig. 1 Typical weld-designed brackets now being used on all types of machinery

How to Design Brackets

◗ *Thought starters on welded design*

MANY different types of brackets, such as motor mountings, pipe supports and machine members, are being designed for welded fabrication from standard steel shapes and forms to suit every requirement of strength, rigidity and product appearance . . . all at lower cost than with other methods.

The supporting member (Fig. 2) is often part of the main machine structure. However, when the bracket is removable, the supporting member is generally a simple flange, flame cut from steel plate; or if the bracket must swing or swivel, the supporting member is made from tubing or bar stock.

Of particular importance to the designer is the construction of the cantilever arm since this member carries the highest unit stresses. Any one of the following cantilever arms can be considered depending upon: (1) basic requirements of the part, (2) permissible cost, (3) available shop equipment, and (4) desired appearance.

This article is published through the courtesy of The Lincoln Electric Co. Cleveland, Ohio.

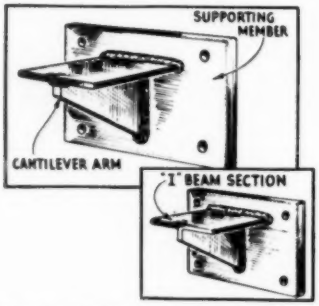


Fig. 2 Simple bracket design with cantilever arm made from flame-cut members or from I-beams

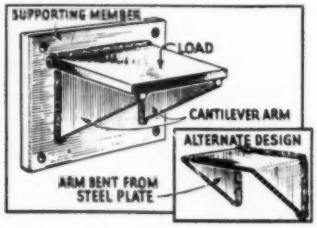


Fig. 3 Alternate design provides additional rigidity. Inset shows bracket built from formed plate

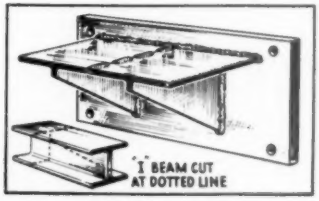


Fig. 4 Cantilever arms constructed from flame-cut I-beams butt welded for increased strength

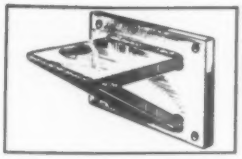


Fig. 5 Rugged channel construction supports heavy loads

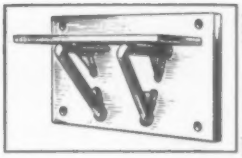


Fig. 6 Tube construction for mountings where low product weight is important

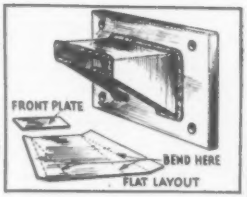


Fig. 7 Box design incorporates sheared and formed plate members

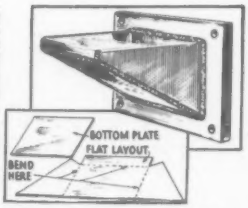


Fig. 8 Totally enclosed box type construction from sheared and formed components

Simplest of bracket designs is shown in Fig. 2, made from separate plate members, flame cut to shape and fillet welded. A similar bracket is also produced by flame cutting the cantilever arm from an I-beam.

Greater strength and rigidity are obtained by using two stiffeners as indicated in Fig. 3. Where bending equipment is available, the bracket may be constructed from one piece, reducing the amount of welding necessary. Two or more arms cut from an I-beam (Fig. 4) can also be used as cantilever arms, butt welding the I-sections with intermittent welds to form a solid, integral unit.

Heavy loads can be carried by the bracket design (Fig. 5) having standard channel sections flame cut to shape and welded as shown. Here again, two or more channel-built brackets can be placed side-by-side and butt welded, providing rugged construction at low cost.

If product weight is to be kept to an absolute minimum, brackets can be built from thin wall tubing bent to shape and welded. Where high unit stresses are involved, gusset plates may be used to provide greater metal section at the joints.

Box-type construction is used where maximum strength is to be combined with product appearance. On relatively thin metal sections, the bracket is sheared from steel plate, then bent to shape in a brake and fillet welded. If the quantity to be made and the shop equipment so permits, the above method is preferred since it minimizes the amount of fitting and welding necessary, thus lowering the cost. On thick plate sections, the component parts must necessarily be flame cut, clamped in a simple fixture and fillet welded.

Figure 7 shows one type of box construction made from two separate pieces with the bottom left open. Totally enclosed box design is illustrated in Fig. 8, where the top, sides and front are formed from a single piece and the bottom is simply a plate welded in place.

Standard shapes and forms like channels may be utilized in several different ways to construct box-type brackets. Two straight channels are butt welded (Fig. 9) to form the simplest box construction. A tapered cantilever arm (Fig. 10) is easily produced by flame cutting one of the channels at the desired angle prior to butt welding. For totally enclosed construction, a steel plate is welded across the front.

Brackets used on heavy machinery such as machine tools and processing equipment are built in several different ways. One method is to make maximum use of standard shapes and forms (Fig. 11). Here, the cantilever arm is made from two channels similar to Fig. 10. The outer box construction is made from flame cut members producing the curved design at the outer portion of the arm.

An alternate method for achieving a modern appearance is to build the totally enclosed box-type construction entirely from flame cut and formed members (Fig. 12). Where desirable, corners can be rounded, and square edges eliminated by incorporating formed sections butt welded to the plates. Weld bead appearance is enhanced by grinding butt welds flush before painting or by welding with the new "Automatic Lincolnweld" or the semi-automatic process.

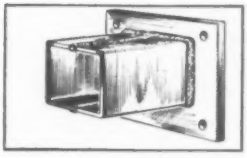


Fig. 9 Box construction using two channels

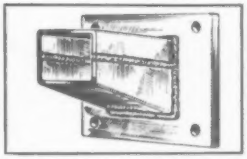


Fig. 10 Tapered box design built from standard channels

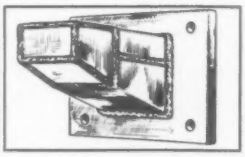


Fig. 11 Totally enclosed box-type construction using both standard channels and flame cut members

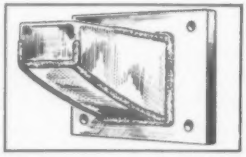


Fig. 12 Improved product appearance with formed members for round edges and corners

Designing for Welding—Part III

by Wallace A. Stanley

WHERE it can be used effectively, resistance welding is not only the fastest and cheapest method of assembling parts, but also usually results in an improved product—stronger, free from service troubles and better looking.

Whether or not resistance welding would be the best method to fabricate any given assembly depends on many factors. Beyond this, final product requirements —size, shape, quantity, surface finish needed—also influence the type of resistance welding process to be used and the type of equipment most suitable for the job.

Of all the factors, however, which go into determining whether resistance welding can save money, improve the product, or both—on any job—is the question: "Is it designed for resistance welding?" Obviously a part to be produced from malleable castings cannot be effectively resistance welded. In many cases however, redesign of the part to enable it to be produced from stampings, etc., will result in a stronger and cheaper assembly. A part designed for resistance welding always can be welded cheaper.

Moreover, even assuming that the assembly calls for use of materials suitable for resistance welding, it is still necessary that the parts be designed in such a manner that resistance welding can be applied with maximum ease and efficiency. Frequently an assembly difficult to weld may lend itself to the process ideally by a simple change in design. Such slight changes frequently result in astounding savings in cost, improvements in product quality, decreased warpage and distortion, elimination of straightening, grinding, and punching of holes, decreased die costs, less expensive punch presses or tools, etc.

Wallace A. Stanley is Application Engineer at the Progressive Welder Co., Detroit, Mich.

While the determination of best design practice for maximum utilization of the advantages of resistance welding depends on a thorough knowledge of resistance welding methods and equipment available, it is possible to list some basic considerations which apply to almost any type of equipment used. Where relatively complicated parts or parts produced in large quantities are involved, it is advisable to consult process engineers thoroughly familiar with modern welding equipment.

SIMPLE SPOT WELDING

In designing a part calling for assembly by spot welding, the following basic considerations are important.

Size of Each Weld

The diameter of each spot weld and in certain cases the diameter of the spot weld nugget, and even the thickness of the nugget itself is a product of any one or combination of the following factors: Size, shape and material of the welding electrode; the amount of welding current used; the duration of that welding current; the welding pressure used; the type and thickness of the material to be welded.

By proper selection of these factors it is possible to produce the desired weld characteristics for each particular job. Where the part is merely a cover or shield, for instance, with no load or strain on the weld, the spot weld itself can be small.

Where the spot weld may be subjected to heavy stresses, spot weld dimensions should provide for this.

Electrode Clearance

Electrode size has an important bearing on product design, since there must be enough clearance to get the electrode and electrode holder in place for welding. Flanges must be wide enough to provide the necessary clearance. (Where it is not practical to provide suffi-

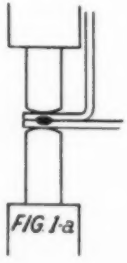


FIG. 1-a

FIG. 1-b

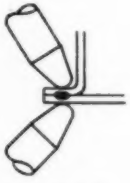


FIG. 1-c

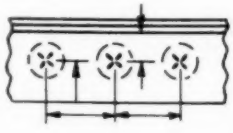


FIG. 2

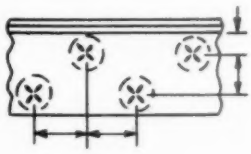


FIG. 3

cient flange width to accommodate standard electrodes (Fig. 1-*a* and 1-*b*) offset electrodes may be used (Fig. 1-*c*) or the part can be designed for projection-welding.)

Distance from Edge

The importance of sufficient clearance for positioning of the electrode is illustrated by the fact that if the weld nugget gets too close to the edge—or the tips actually overlap the edge—inferior welds will be produced (Fig. 2). There should be sufficient metal all around the weld to retain all the molten metal in place. If possible, where a narrow welded edge is desired, final trimming may be scheduled to *follow* rather than precede the welding operation.

Spacing of Spots

Do not design the part so that the number of spot welds required to give the desired joint strength will be too close together (Fig. 2). Where spot welds are too close, part of the current for the second weld will escape through the finished first weld, weakening the second weld, and so on. Usually a stronger joint will be produced using even fewer welds, farther apart. Where a joint requires a considerable number of welds—as for a long lapped joint—it is advisable to allow sufficient overlap of metal so that two or more rows of spots, spaced diagonally and well apart, can be welded (Fig. 3).

Sheer Strength

If these considerations are followed it is quite simple to establish definite design values for minimum shear strength of spot welded joints—a specification easy for inspection to check for maintenance of quality in production. This can be done simply by welding test samples from scrap metal and checking the shear strength by pulling.

(*Continued in next issue*)

Welded Aluminum Boats

THE Southwest Mfg. Co., Little Rock, Ark., now produces aluminum boats with all-welded seams. Their former method of riveting seams resulted in numerous complaints about leaks. They stopped these complaints quickly and raised speed of production 300% by using the Heliarc inert-gas-shielded arc-welding process.

In this process the electrode and the weld puddle are blanketed in argon, an inert gas. This prevents oxidation of the electrode and the weld metal. An outstanding characteristic of the process is that, with the exception of copper, 1/4 in. or thicker, flux is not required in the welding of any of the common commercial metals and alloys. This does away with the possibility of corrosive flux inclusion and the welds are clean and nonporous.

Fig. 1 Welding operators making corner welds without addition of filler rod

Fig. 2 View of completed boat

Figure 1 shows the jig set up for welding all seams. The aluminum sheeting is clamped to a steel frame while the operators make corner welds without adding any filler rod. Heliarc HW-4 torches with 3/32-in. diameter tungsten electrodes are used for all welds. The boats are made from 28-1/2H aluminum; 0.040 in. thick for the sides and 0.051 in. thick for the bottom. The parts are sheared to shape and it requires only 30 min. for two operators to complete all jigging and welding operations on each boat. No finishing is necessary after the seams are welded.

Current used is high-frequency stabilized alternating current, 175 amp. The argon flow is 17 cu. ft. per hour. The welding speed is 30 in. per minute. Rapid welding rates and high arc concentration of the Heliarc process result in small heat spread and make warpage negligible.

At the present time, the boats are produced in two sizes, 12- and 14-ft. lengths. Air chambers added to the bow and in the middle of these boats make them practically unsinkable.

Photographs are through the courtesy of The Linde Air Products Co.

Robbery in the Welding Shop

Loose cable connections and small inefficient cable size add to the resistance and power loss of the circuit. Poor electrode holders add to the discomfort of the operator

by R. L. Townsend

CONDITIONS that have been permitted to exist in welderies all over the country for years on end have robbed the profits of many a business to an extent hard to calculate and hard to believe by the average owner of a business engaged in the fabrication of metal. I am referring to the inefficient operation of electric welding equipment in all types of shops, large and small.

The finest welding machine on the market with the most skilled operator using the best of electrodes, cannot deposit weld metal economically or efficiently if the welding cables and their connections are undersize or improperly connected. Without question the greatest waste of time, equipment, electrical energy and man-hours in the welding process is caused by the use of faulty cables and connections. Top management in many welderies all over the country walk through their shops totally unaware of this "Leakage Robbery" that is perhaps equal to their total net profit.

THE CABLE

Without welding cable to transmit the electrical energy the electric welding process would be an inflexible proposition. To weld we must have a welding machine, cables with proper connections and welding wire. Then there is the matter of power supply and skilled operator. A fact which has probably not had your consideration is that every one of the elements concerned with electric welding has had vast improvement over the past several years with the exception of the welding cable and size for size it is carrying a much heavier load than it did in 1920, 1930 and possibly in 1940. Along about 1934 or '35 they stepped up the voltage on welding machines from 25 to 40, making it possible for cable to carry welding energy greater distances and to better overcome poor connections, even though the losses were greater. Going to the other end of the cable circuit, the "business end" where metal is flowing into the bead, there has been a vast transformation witnessed by many of us. In 1927–28 bare or washed welding wire was the order of the day. Today our modern covered electrode uses a much larger current and with almost double the load factor.

Let's again go back to the welding cable. It is still the same with possibly better covering than it had 20 years ago. The copper strands going into it are still of the same size and have the same current carrying capacity. The current it carries today is higher powered in both a. c. and d. c. with high frequency thrown in. It still carries the current to electrodes that deposit metal two times, yes, three times faster than their bare predecessors. Without question it is doing two to three times the amount of work required of it by both machines and electrodes in 1929.

For a clearer understanding, let's start thinking of this cable as a pipeline. It really carries current even though you can't see, smell, hear or normally feel it.

Welding current does have volume and pressure just like water, gas or oil in a pipeline, but we know it by amperage and voltage. I am sure everybody understands the mechanics of volume and pressure when they are attempting to water the far corner of their garden with a hose that is not long enough. If you can't get enough volume by opening the valve wide at the side of the house, you try to regulate it by pressure at the nozzle. By the same token, you regulate the volume and pressure or amperage and voltage in the electric welding process. Now, with this understanding it is hard to reason why the users of the electric welding process will blindly use welding cables so small or poorly connected that they all but scream their inefficiencies to the welding operator, the welding foreman, the shop superintendent, the general manager and the "old man" himself. If only welding power that is lost out of the circuit between the machine and the electrode would run out all over the floor a blood red or smell to high heaven I am sure something would be done to correct its sly and cunning inefficiency. Granted that power is cheap, its inefficient use is really only secondary to the great loss it causes. I refer to the loss of time of the welding operator who has no intention wasting his time that you are paying him for at the rate of from $1.00 to $2.50 and $3.00 per hour. When he has the "hot hand" the law of self pre-

R. L. Townsend is a partner in the Tweco Products Co., Wichita, Kans.

This paper was presented before the Wichita, Colorado and Kansas City Sections of the AMERICAN WELDING SOCIETY.

servation is naturally going to take over regardless of what you are paying him. Your sympathy and dollars go out to him in this "hand cooling" operation. If the operator isn't getting the kind of current he wants at the arc to perform the job at hand he naturally goes back to the machine to "gin it up." Of course, you are paying him for this walking time whether it be once a day or a dozen or more times. Walking time doesn't come any cheaper than "hand cooling" time. A welding operator trying to set his machine to a desired heat for a specific job with a changing variable in a loose connection and a high resistant cable cannot use his time efficiently or turn out uniform welds regardless the amount of checking the welding engineer or electrician does with meters. Predetermined job amperages and voltages fall by the wayside. A pail of water by the operator is one of the best signs in the world that inefficiency exist. You all know what it is for—and it isn't drinking water.

THE HOLDER

A big ball of tape on the holder handle is another sure sign. It probably cost no less than $2.00 or $3.00 in operator's time to install and that did not cure the trouble as the operator's blistered hand will probably bear out. Management will do well to inspect their operator's hands and listen to their gripes about hot holders, machines turning cold and rods not performing. One complaint may be dismissed as a "tempermental operator," but if two or more have the same story it is time to do a little sleuthing. It ordinarily does not take a "Sherlock Holmes" to find the trouble.

The man-hour losses we have been talking about plus the power losses reflect definitely in the companies' net profit. There is no salvage value to work not performed during a given period of time recorded by the time clock.

Management, and I mean to include top management; must be made conscious of their loss and be trained to recognize a loss of this kind when they see it. The president of a pipeline or his superintendent walking down his pipeline would recognize immediately an oil or gas leak, but the welding operator nearby nursing a weak and sputtery arc normally causes no concern. There is a crying need for trained management and supervision over the "pipelines of welding." A trained walker of welding cable pipelines will pay big dividends whether you have one welding machine or one hundred. It is time to start looking for the causes of weak arcs, hot holders, sputtery grounds and sparking cables. Add to the list hot cables, hot machines and red hot operators with blistered hands. You are paying plenty every day if you permit these conditions to exist in your shop. There is a correct solution to every one of these problems and it will pay big dividends to find that solution. This is certainly a universal shop problem that will pay off only with eternal vigilance.

Puts Scrap Metal to Profitable Use

INSTEAD of allowing scrap pipe and plate to rust uselessly in a corner, one welding shop got out its oxyacetylene cutting attachment and arc welder and made these metals pay dividends.

They built a stand to hold a fuel oil meter for bulk tank truck loading. The plates shown in the illustrations were flame trimmed and the holes for the bolts and pipe line, flame cut. An Airco 700 torch with cutting attachment was used.

Figure 1 shows the operator arc welding the pipe to the plate. The current setting was 125 amp., reverse polarity. Figure 2 shows the finished job. Cost—$10.

Photographs are through the courtesy of the Air Reduction Sales Co.

Arc welding fuel oil meter stand from scrap pipe and plate

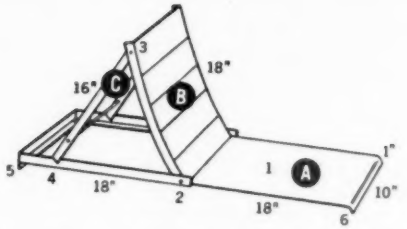
Welded fuel oil meter stand—scrap pipe and plate

An Unusual Truck Chock

By Harry Beasley

THE chock, shown in the drawing, is placed behind a rear wheel of truck which is then backed up until the wheel rests on surface *A* (a piece of $^3/_{16}$-in. plate bent down at the end to catch the ground) and against surface *B* (angle iron and scrap plate).

Points *5* and *6* are hardfaced and will dig into almost any surface. Brace *C* holds *B* in position and "it stays put."



The part back of *B* is made of 2- x 2- x $^7/_{16}$-in. angle iron welded at the corners.

When not in use, point *4* folds back on hinge *3* to a point near *2* and *B* drops flat.

Data and illustration supplied by Air Reduction Sales Co.

Heat Treatment of Field Welds in Steam Piping

by R. O. Jackson

FOLLOWING the requirements of the A.S.A. Code for Pressure Piping, we use proved and accepted procedures covering materials as well as the making of the welds in 0.5% chromium–0.5% molybdenum main steam piping. These procedures were worked out by our company and the Pioneer Service and Engineering Co., Chicago. A portion, of course, covers preheat and post-heat required to complete the welds. Good equipment is essential and it must be used under supervision of qualified personnel. Our company uses technical men for this work.

DESCRIPTION OF HEAT-TREATING EQUIPMENT

We use a 3-phase, electrical resistance type automatic heater. This unit is complete with all the necessary equipment including charts, material for cams and potentiometer unit mounted in a portable panel. It may be used on either 220 or 440 v. by the use of a transfer switch on the panel. However, for use on 440 v., two coils must be connected in series across each phase which you plan to use. Temperature for control of the unit is by thermocouple (T.C.) which is usually attached to the pipe near the weld for preheating by tacking a grooved nut on the pipe. Then the T.C. wire is put through the groove and a bolt tightened down on the T.C. We have tried several methods, but this is the more convenient. After the weld is finished the T.C. bolt is moved onto the weld proper.

R. O. Jackson is with the Oklahoma Gas and Electric Co., Harrah, Okla.

A portion of a Lecture for the Oklahoma City Section of AMERICAN WELDING SOCIETY'S 1948 Educational Series.

For preheating, say a 10-in. pipe to pipe joint, we use two 10-in. coils, one on each side of the joint, making sure that there is room left over the weld for the third coil which will be used for stress relief. The machine is hooked up, turned on and the predetermined preheat temperature is set on the controls. The machine will bring it up to temperature and hold it while the weld is being made. Then the third coil is placed over the weld and hooked up (cut off machine for connecting) and the machine is turned on and use is made of the cam for bringing it up to stress-relief temperature at the predetermined rate of temperature rise. The weld is held at that temperature for the required amount of time and then brought down gradually to 1100° F. where the machine is normally cut off and the weld allowed to cool naturally. An insulating blanket of $^1/_4$-in. felted asbestos must be used over the coils to hold the heat and to prevent the coils from sagging.

HEAT TREATMENT

We use a minimum preheat temperature of 400° F., raising this to perhaps 500 or 600° F. for complex joints.

For bringing up to post heat or stress-relief temperatures, we use a rate of 300° per hour to 1325° F. ± 25° and held not less than 3 hr. per inch of thickness with the heaviest wall thickness governing the time. Again if the joint is complex, this time is increased to not more than 4 hr. per inch of thickness.

As a precautionary measure against burning the coils out, each coil should be pushed back to its original length before reusing. Also, for oddly shaped joints, where the coils are likely to come in contact with the pipe, a sheet of $^1/_{16}$-in. thick asbestos blanket may be

used on the pipe before wrapping with the coils to prevent burn outs. Do not allow the welder to weld the joint if the coils are not well wrapped to prevent spatter from shorting the coils or the welder from being burned.

Two very good papers, which were recently published in THE WELDING JOURNAL, give a description and discussion of heat treatment of this particular class of welds. These papers are: "A Study of Properties of 0.5% Chromium – 0.5% Molybdenum Pipe Steel," by R. C. Fitzgerald, A. B. Wilder, G. B. Smith, and A. E. White, September 1948, and "Weldability of Cast Low-Alloy Steels," by V. T. Malcolm and S. Low, December 1948.

Loose-Ring Harrow

by J. P. Fairbank

THIS plan shows the construction details of a simple type of flexible harrow, designed primarily for use on pastures. See "Irrigated Pastures in California," by Burle J. Jones and J. B. Brown, California Agricultural Extension Service Circular 125.

This harrow is useful also for reseeding, seedbed preparation and weeding. The flexibility permits the teeth to dig the low spots as well as the high spots.

This type of harrow should be pulled at speeds of three to four miles per hour as it may choke in trashy ground if operated at very low speeds. The speed should be high enough to make the units "dance" and thus clear themselves of trash.

The harrow is made up of units of four, regular heat-treated harrow teeth welded to two rings having an outside diameter of 12 in. Each ring is made from a 36-in. length of $\frac{1}{2}$-in. round mild steel rod. The units are connected by loose fitting links *A*, the closures being bent down to the center bar and welded after assembling. The purpose of the center bar in *A* is to restrain the units from becoming entangled with each other. The removable link *B* may be used instead of *A* if it is desired to remove units singly or in groups. The *A* link has the advantage of no bolts and nuts to lose. The triangular draft links are used on the front and rear to attach the draft and drag chains.

The purpose of the pipe or bar across the rear is to drag down on the rear units. The draft and drag bars are made longer than the assembled width of the units to act as spreaders and aid in making short turns with the harrow.

The illustration shows a harrow made up of 16 units, four rows each way. Any desired number of units can be assembled to make larger or smaller harrows. The 16-unit harrow shown in this plan weighs about 200 lb.

The construction of this harrow is suited to arc welding, with only a few simple shapes easily replicated. Badly worn teeth can be built up or extended by arc or gas welding.

J. P. Fairbank is with the Division of Agricultural Engineering, University of California, Davis, Calif.

Data furnished through the courtesy of The Lincoln Electric Co., Cleveland 1, Ohio.

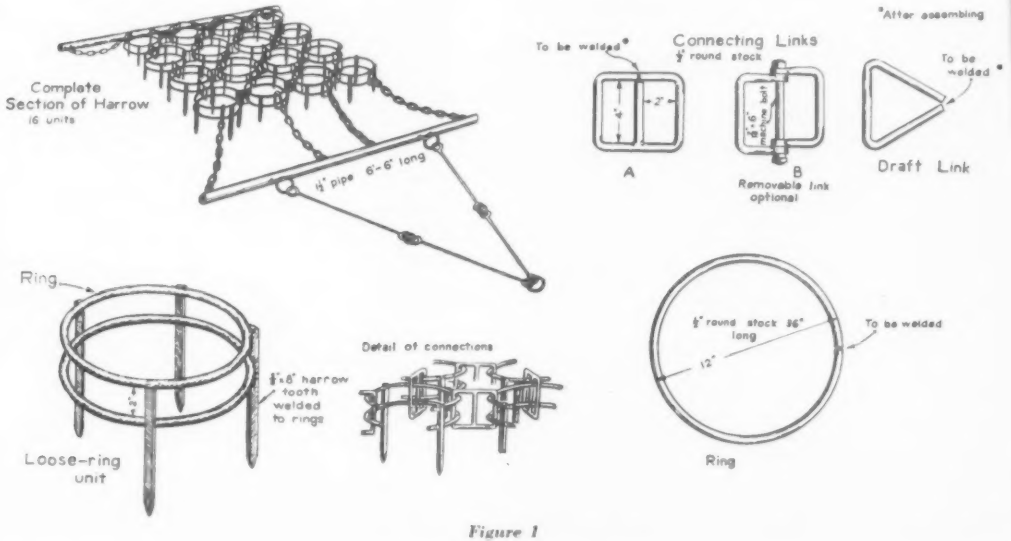


Figure 1

the AMERICAN WELDING SOCIETY

activities • related events

Western Metal Congress

Again the Western Metal Congress and Exposition, staged by approximately 20 cooperating technical societies and applying to oil, chemical, manufacturing, aviation, mining and other western industries, will be held in California.

Marking the sixth time the combined educational sessions and exhibition have been held on the coast, the double event is dated for April 11th to 15th in Shrine Convention Hall, Los Angeles.

William H. Eisenman, secretary of the American Society for Metals, Cleveland, has arrived in Los Angeles to take active charge. His headquarters are at 3232 Royal St., adjacent the display hall.

Newest developments in producing, fabricating and applying ferrous and nonferrous metals, he said, will be described at the technical sessions. Authoritative speakers from all parts of the United States will deliver papers.

Displays, he further said, will be both operating and nonoperating. They will demonstrate what is new or improved in metals, metal working equipment and processes. Ferrous and nonferrous metals, welding supplies and equipment, heat-treating equipment and service, foundry supplies, inspection aides, materials handling, metal cutting, machining equipment and tools will be exhibited.

A local general committee, numbering 70 and headed by E. R. Babylon of the Kaiser Co., Los Angeles Chapter Chairman of A.S.M., has spent six months planning the affair.

Technical sessions will be presented by A.S.M., AMERICAN WELDING SOCIETY, American Foundrymen's Society and American Institute of Mining and Metallurgical Engineers.

In addition, the following societies are cooperating in various ways:

American Chemical Society, Society for Nondestructive Testing, American Institute of Electrical Engineers, American Petroleum Institute, American Society of Civil Engineers, American Society of Mechanical Engineers, American Society for Testing Materials, Pacific Coast Electrical Assn., Pacific Coast Gas Assn., Purchasing Agents Assn., Society of Automotive Engineers, Western Oil and Gas Assn. and others.

Invitations to attend the exposition will be issued to members of all cooperating technical societies and to users and potential users of exhibited products and devices. Although attendance will be limited to industrial plant operators, department heads and technical engineers, 60,000 persons from the western states are expected to view the displays.

The Congress and Exposition last was held in Oakland two years ago.

Western Metal Congress Committees

A local general committee, numbering 70 and headed by E. R. Babylon of the Kaiser Co., Los Angeles Chapter Chairman of the American Society for Metals, has been busy for six months planning the Western Metal Congress and Exposition, April 11th to 15th, Shrine Convention Hall, Los Angeles.

AMERICAN WELDING SOCIETY's Program Committee—Hugo W. Hiemke, California Alloy Products Co.; Charles Babbitt, California Metal Corp.; Wendell Chapman, Denton & Anderson Co.; Alan Flanigan, University of California, Westwood; Godfrey Grable, Terminal Island Naval Shipyard; Robert Madden, Kaiser Steel Co.; Alex Maradudin, Standard Oil Co. of California; Paul Marking, Precision Weld Facing Div., Apex Steel Corp.; Clint Swift, C. F. Braun & Co.

Officers of Los Angeles Chap.er A.W.S. are: Ed Williams, Victor Welding Equipment Co., chairman; Charles Haynes, C. F. Braun & Co., vice-chairman; Charles Johnson, Victor Welding Equipment Co., secretary.

Western Metal Congress

An impressive educational program will be presented by the AMERICAN WELDING SOCIETY at the Western Metal Congress and Exposition, April 11–15th in Shrine Convention Hall, Los Angeles, E. O. Williams, chairman of the SOCIETY's LOS Angeles Chapter, has announced.

Hugo W. Hiemke, manager, California Alloy Products Co., South Pasadena, is serving as program chairman. The program is printed elsewhere in the JOURNAL.

Commenting on the program, Hiemke said, "We also are planning to hold three panel discussions on as many evenings. These will be educational meetings of the question and answer type.

"Subjects will be welding metallurgy, design for welding and aircraft welding."

Technical programs also will be presented by the American Society for Metals, American Foundrymen's Society and American Institute of Mining and Metallurgical Engineers.

The exposition will demonstrate what is new or improved, and metals, metal working equipment and processes. Ferrous and nonferrous metals, welding supplies and equipment, heat-treating equipment and service, foundry supplies, inspection aids, materials handling, metal cutting, machining equipment and tools will be exhibited.

Other cooperating societies include: American Chemical Society, Society for Non-Destructive Testing, American Institute of Electrical Engineers, American Petroleum Institute, American Society of Civil Engineers, American Society of Mechanical Engineers, American Society for Testing Materials, American Society of Tool Engineers, Pacific Coast Electrical Association, Pacific Coast Gas Association, Society of Automotive Engineers, Western Oil and Gas Association, National Association of Purchasing Agents and Purchasing Agents Association of Los Angeles.

Tentative Technical Program, American Welding Society—Western Metals Congress

Los Angeles, April 11–15, 1949

Monday, April 11th

9:30 A.M. at Biltmore Hotel

AUTOMATIC WELDING

"Tandem-arc Submerged-Melt Welding of Line Pipe." By Charles A. Babbitt, Vice-Pres., Cal-Metal Corp., 1157 W. Maple St., Torrance, Calif.

"Automatic Welding of Pressure Vessels." By Clinton E. Swift, Weld Engr., C. F. Braun & Co., 1000 S. Fremont Ave., Alhambra, Calif.

"Developments in Automatic Hard Facing." By H. W. Sharp, Chief Met., The Stoody Co., Whittier, Calif.

2:00 P.M. at Shrine Convention Hall

WELDING RESEARCH

"Welded Ship Failures and Their Relation to Other Structures." By E. Paul DeGarmo, Assoc. Prof. of Mech. Engr., University of California, Berkeley, Calif.

"Brittle Fracture of Mild Steels and Heat-Treated Alloy Steels." By Earl R. Parker, Assoc. Prof. of Phys. Met., University of California, Berkeley, Calif.

"Recent Researches on the Metallurgy of Welding." By Alan E. Flanigan, Asst. Prof. of Engr., University of California, Westwood, Calif.

New Electrode Cuts Hardsurfacing Cost for Tools and Dies

By G. W. Woods, Development Engineer
The Lincoln Electric Company, Cleveland, Ohio

"Toolweld A&O" (air and oil hardening) deposits tool and die steel hardsurfacing for building, repairing and altering punches, dies, shears and other metal forming tools. The deposits are dense and of high strength with unusual resistance to deformation or failure under impact. In addition, the deposits have exceptional resistance for metal-to-metal wear as well as excellent edge-holding properties. "Toolweld A&O" has an as-deposited hardness of 61 to 65 Rockwell C and a broad hardening temperature range ideal for work with a wide variety of tool steels. *"Toolweld A&O" sells for less than one-third the price of other electrodes for similar service.*

"Toolweld 60" deposits high speed steel hardsurfacing for repairing and altering high speed steel cutters, lathe tools, hot shears, or any applications where high operating temperatures are encountered. "Toolweld 60" can be used also for lower cost fabrication of turning and forming cutters incorporating a plain carbon or low alloy base hardsurfaced with high speed steel.

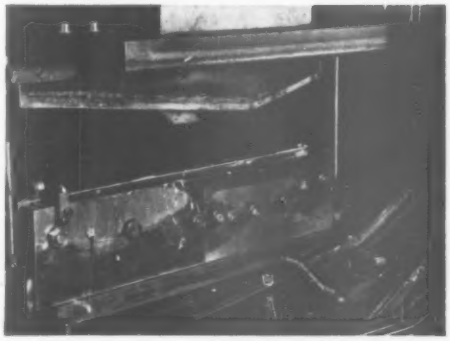


Fig. 1. This die built of mild steel hardsurfaced with "Toolweld A&O" is used for brake-forming channel sections from hot rolled steel strips. The built-up die outlasts the original many times in spite of the presence of hard scale on the hot rolled steel to be formed.

There is a Lincoln electrode for every essential hardsurfacing need. The Lincoln Hardsurfacing Guide (Fig. 3) enables quick selection of the proper electrode for any practical requirement of abrasion and impact, *assuring you the longest wear at the lowest price.*

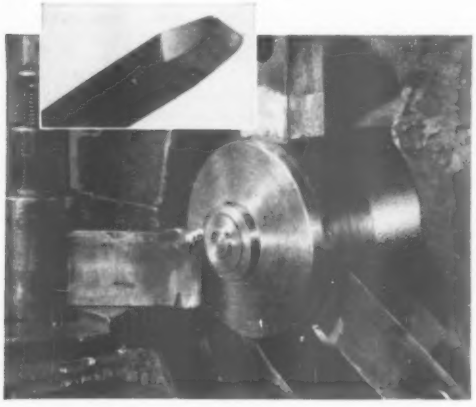


Fig. 2. Lathe cutter for steel mill maintenance shop, hardsurfaced with "Toolweld 60," machining end of heavy steel bar. Inset shows cutter hardsurfaced, ground and ready for use.

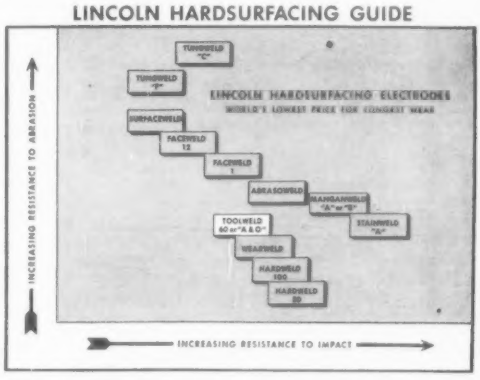


Fig. 3. Lincoln Hardsurfacing Guide for selecting proper hardsurfacing electrodes. Available without cost to welding engineers. Write for it.

The above is published by **THE LINCOLN ELECTRIC COMPANY** *in the interests of progress.*
For further information, ask for Weldirectory for Hardsurfacing, Bul. 466 The Lincoln Electric Company, Dept. 93, Cleveland 1, Ohio.

8:00 P.M. at Shrine Convention Hall

PANEL DISCUSSION MEETING—WELDING METALLURGY

Panel of Experts: C. B. Voldrich, Ch. Weld Engr., Battelle Memorial Institute, Columbus, Ohio; E. R. Parker, Assoc. Prof. of Phys. Met., University of California, Berkeley, Calif.; Alex Maradudin, Materials Engr., Standard Oil of California, El Segundo, Calif.; Alan E. Flanigan, Assoc. Prof. of Enggr., University of California; Westwood, Calif.; Donald S. Clark, Assoc. Prof. of Mech. Enggr., California Institute of Technology, Pasadena, Calif.

Tuesday, April 12th

9:30 A.M. at Biltmore Hotel

ELECTRODES—CUTTING—BRAZING

"Electrodes, Their Coatings and Influences." By John J. Chyle, Dir. of Weld. Res., A. O. Smith Corp., Milwaukee, Wis.

"Arc-Air Cutting and Gouging." By Myron D. Stepath, Weld. Engr., Puget Sound Naval Shipyard, Bremerton, Wash.

"Strength of Silver-Brazed Joints." By A. M. Setapen, Tech. Sales Dept., Handy & Harman Co., New York, N. Y.

Tuesday afternoon open to visit Exhibits.

8:00 P.M. at Shrine Convention Hall

PANEL DISCUSSION MEETING—WELDING DESIGN CLINIC

Panel of Experts: LaMotte Grover, Struc. Engr. Tech Serv. Div., Air Reduction Sales Co., New York, N. Y.; E. Paul DeGarmo, Assoc. Prof. of Mech. Enggr., University of California, Berkeley, Calif.; M. H. MacKusick, Cons. Engr., Technical Welding Service, Los Angeles, Calif.; F. J. Pilia, Res. Engr., Linde Air Products, New York, N. Y.; R. T. Gillette, Weld. Engr., Works Lab., General Electric Co., Schenectady, N. Y.

Wednesday, April 13th

9:30 A.M. at Biltmore Hotel

INERT-GAS SHIELDED-ARC WELDING

"The Application of Inert-Gas Arc-Welding to Airframes and Engines." By Tom E. Piper, Ch. Proc. Engr., Northrup Aircraft, Inc., Hawthorne, Calif.

"Welding with the Aircomatic Process." By E. H. Roper, Asst. Mgr., Tech. Sales Div., Air Reduction Sales Co., New York, N. Y.

"Heliarc Welding in Production." By F. J. Pilia, Res. Engr., Linde Air Products Co., Newark, N. J.

2:00 P.M. at Shrine Convention Hall

WELDING NONFERROUS ALLOYS

"New Developments in the Welding of Aluminum." By C. B. Voldrich, Ch. Weld. Engr., Battelle Memorial Institute, Columbus, Ohio.

"Welding of High-Nickel Alloys." By Kenneth M. Spicer, Tech. Serv. Dept., International Nickel Co., New York, N. Y.

"Resistance Welding of Nickel Alloys." By Frank G. Harkins, Weld. Engr., Solar Aircraft Co., San Diego, Calif.

8:00 P.M. at Shrine Convention Hall

PANEL DISCUSSION MEETING—AIRCRAFT WELDING

Panel of Experts: Tom E. Piper, Ch. Proc. Engr., Northrop Aircraft, Inc., Hawthorne, Calif.; Frank G. Harkins, Weld. Engr., Solar Aircraft Co., San Diego, Calif.; Charles E. Smith, Proc. Engr., Douglas Aircraft, Long Beach, Calif.; Fred Pipher, Weld. Engr., Lockheed Aircraft, Burbank, Calif.; Bert Gross, Dir. of Res., Rohr Aircraft, Chula Vista, Calif.

Thursday, April 14th

9:30 A.M. at Shrine Convention Hall

RESISTANCE WELDING

"Resistance Welding—History, Design, Control and Application." By Robert T. Gillette, Weld. Engr., Works Lab., General Electric Co., Schenectady, N. Y.

"Some Developments in Resistance Welding Controls." By Eugene Lica, Electrical Engr., Douglas Aircraft Co., Santa Monica, Calif.

"Single-phase Resistance Welding Machinery." By J. H. Copper, Ch. Sales Engr., Taylor-Winfield Corp., Warren, Ohio

Thursday afternoon open to visit Exhibits

Thursday evening—Joint Banquet with A.S.M., Biltmore Bowl.

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Oxy-Acetylene	"40" Monel Gas Welding Wire	For welding Monel* using INCO "3" Gas Welding and Brazing Flux
Oxy-Acetylene	"43" Monel Gas Welding Wire	For welding heavy sections of Monel for acid pickling service—no flux required
Metal-Arc	"130X" Monel Welding Electrode D.C.	For welding Monel
Submerged Melt	"50" Monel Wire	For welding Monel
Inert Gas Metal-Arc	"60" Monel Wire	For welding Monel

NICKEL

Oxy-Acetylene	"41" Nickel Gas Welding Wire	For welding of pure Nickel—no flux required
Metal-Arc	"131" Nickel Welding Electrode D.C.	For welding pure Nickel or "L" Nickel; and Monel or Nickel to steel
Submerged Melt	"51" Nickel Wire	For welding pure Nickel
Inert Gas Metal-Arc	"61" Nickel Wire	For welding pure Nickel

INCONEL

Oxy-Acetylene	"42" Inconel Gas Welding Wire	For welding Inconel* using INCO "2" Gas Welding Flux
Metal-Arc	"132" Inconel Welding Electrode A.C.-D.C.	For welding Inconel; and Inconel to steel
Submerged Melt	"52" Inconel Wire	For welding Inconel
Inert Gas Metal-Arc	"62" Inconel Wire	For welding Inconel

70/30 COPPER-NICKEL

Oxy-Acetylene	"47" 70/30 Copper-Nickel Gas Welding Wire	For welding 70/30 Copper-Nickel using INCO "1" Gas Welding and Brazing Flux
Metal-Arc	"137" 70/30 Copper-Nickel Welding Electrode D.C.	For welding 70/30 Copper-Nickel
Submerged Melt	"57" 70/30 Copper-Nickel Wire	For welding 70/30 Copper-Nickel

"K" MONEL

Oxy-Acetylene	"44" "K" Monel Gas Welding Wire	For welding "K"* Monel, using 2 parts INCO "2" Gas Welding Flux and 1 part Lithium Fluoride
Metal-Arc	"134" "K" Monel Welding Electrode D.C.	For welding "K" Monel
Inert Gas Metal-Arc	"64" "K" Monel Wire	For welding "K" Monel

LUKENS

NICKEL-CLAD STEEL

Metal-Arc	"131" Nickel Welding Electrode D.C.	For welding Nickel side only

"L" NICKEL-CLAD STEEL

Metal-Arc	"131" Nickel Welding Electrode D.C.	For welding "L"* Nickel side only

MONEL-CLAD STEEL

Metal-Arc	"130X" Monel Welding Electrode D.C.	For welding Monel side only

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Metal-Arc	"133" 80/20 Nickel-Chromium Welding Electrode A.C.-D.C.	For welding Inconel side only; and solid Inconel to steel

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NICKEL (INCO TRADE MARK) ALLOYS

THE INTERNATIONAL NICKEL COMPANY, INC., 67 Wall St., New York 5, N.Y.

Friday, April 15th

9:30 A.M. at Shrine Convention Hall

CODES, SAFETY, INSPECTION

"Recent Changes in Pressure-Vessel Codes." By Elmer O. Bergman, Cons. Engr., C. F. Brau & Co., Alhambra, Calif.

"Introducing the New California Code for Compressed Gases." By George A. Sherman, State of California, Division of Industrial Safety, San Francisco, Calif.

"Non-Destructive Testing of Welded Refinery Equipment." By S. J. Artese, Test Engr., Shell Chemical Co., Wilmington, Calif.

Metals Exposition

Cleveland, Ohio, will be host to the Metal Congress and Exposition in 1949 when the National event has its 31st annual meeting at the city's huge Public Auditorium on October 17th to 21st.

W. H. Eisenman, National Secretary, American Society for Metals, and Managing Director of the Congress and Exposition, announces that floor plans for the Cleveland show will be in the hands of previous Exposition exhibitors February 1st, and that space assignments will be made March 12th.

"Details for handling a record breaking attendance of men in the metals producing and metals consuming industries have been worked out," said Eisenman, "and hundreds of important companies plan to demonstrate, not only their new products and services, but also effective means of further contributing to lower production costs."

The "Metal Show," largest of its kind in the world, will require the entire space of both floors of the Public Auditorium as well as all of the area underground . . . . 250,000 sq. ft.

The Housing Bureau, always important to the comfort of the thousands who attend the event, has already been set up and is functioning under the able direction of Mrs. Louise D. Perkins. The Housing Bureau's permanent address—511 Terminal Tower, Cleveland 13, Ohio.

Board of Directors Meeting

A Board of Directors meeting was held in the Engineers' Club, New York City, on Friday, Jan. 21, 1949, with the following in attendance:

Members: C. A. Adams, D. Arnott, J. J. Chyle, D. H. Corey, R. S. Donald, O. B. J. Fraser, J. H. Humberstone, C. I. MacGuffie, L. S. McPhee, J. F. Maine, F. L. Plummer, H. W. Pierce and G. M. Trefts III.

By Invitation: A. C. Weigel.

Staff: J. G. Magrath, M. M. Kelly, W. Spraragen and F. J. Mooney.

After explaining that his reason for being in the chair was due to the sudden illness of President Sieger, O. B. J. Fraser, First Vice-President, called the meeting to order at 10:08 A.M.

The Board members were very sorry to learn of Mr. Sieger's illness and expressed their sincere hope for a rapid and complete recovery.

Committee Appointments

Educational Committee—Addition. Recommendation of the Chairman of the Educational Committee for the appointment of Prof. C. Arthur Peterson, Asst. Prof., Mechanical Metallurgy, M.I.T., was approved.

Constitution and By-Laws Committee—Substitution. It was reported that at the Board meeting last October, H. M. Priest was named Chairman, and H. O. Hill and K. L. Hansen, members of the Committee on Constitution and By-Laws. Acceptances were received from Priest and Hill. Mr. Hansen declined because of obligations that required his full time. A. J. Raymo, Baldwin Locomotive Works, was proposed and approved.

Memorial Resolutions. Upon motion, duly seconded, appointment of the following Resolutions Committees, made by President Sieger, were confirmed:

Committee on Resolutions for W. D. Halsey: H. C. Boardman and C. W. Obert were named.

Committee on Resolutions for W. F. Carson: R. D. Thomas and W. W. Barnes were named.

Committee on Resolutions for A. M. Unger: R. E. McFarland and E. R. Seabloom were named.

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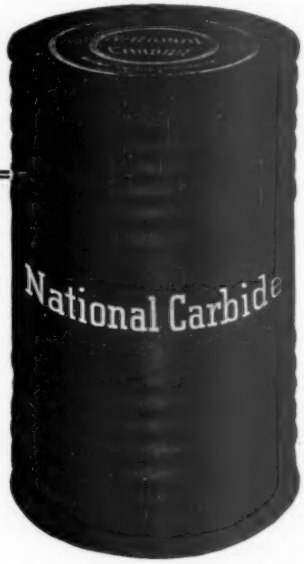

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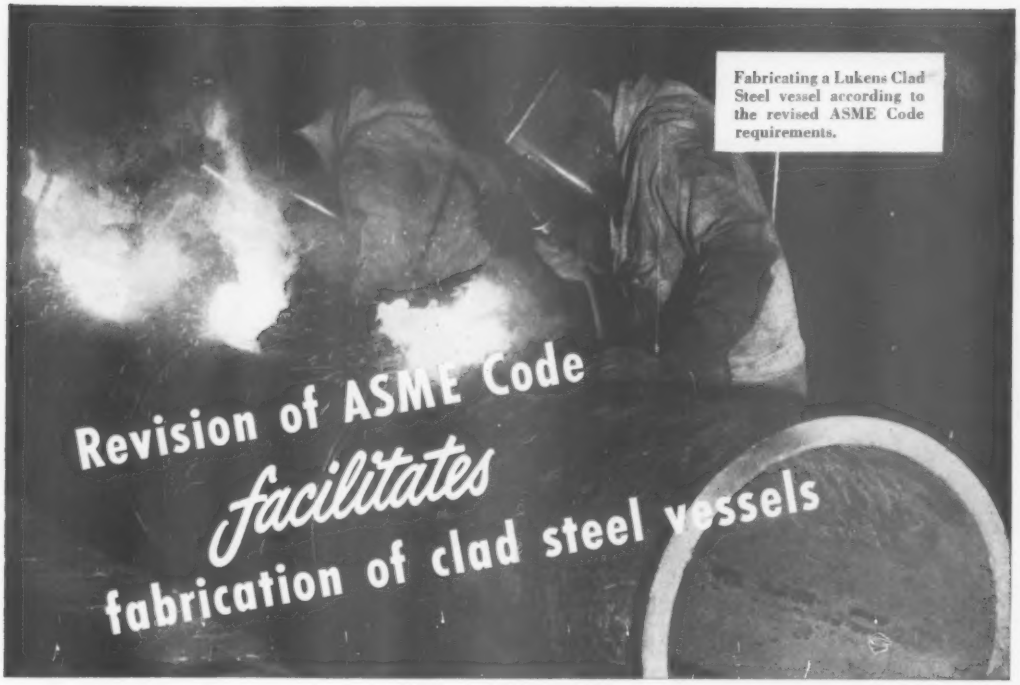


Fabricating a Lukens Clad Steel vessel according to the revised ASME Code requirements.

As announced recently in Mechanical Engineering, Case 896 of the ASME Code has been further revised. Rulings cover welding procedure and operator qualification requirements, with the result that, in many cases, the fabrication of clad steel equipment is facilitated and speeded up.

All-alloy welds can be used throughout the entire section of a clad steel shell where the small diameter, for example, makes this necessary. Materials meeting Specification SA-263, Grade A (Type 410) can be used without stress relief if the carbon content of the cladding is less than 0.08. Temperature limitations for certain types of clad metals have been modified.

Case 1078, covering the use of linings which are applicable to certain fittings—manways, nozzles and the like—is also now available for the first time.

For general information on Lukens Nickel-Clad, Stainless-Clad, Inconel-Clad and Monel-Clad Steels, write for Bulletins 255 and 338. Lukens Steel Company, 407 Lukens Building, Coatesville, Pennsylvania.

CLAD METAL STEEL

LUKENS

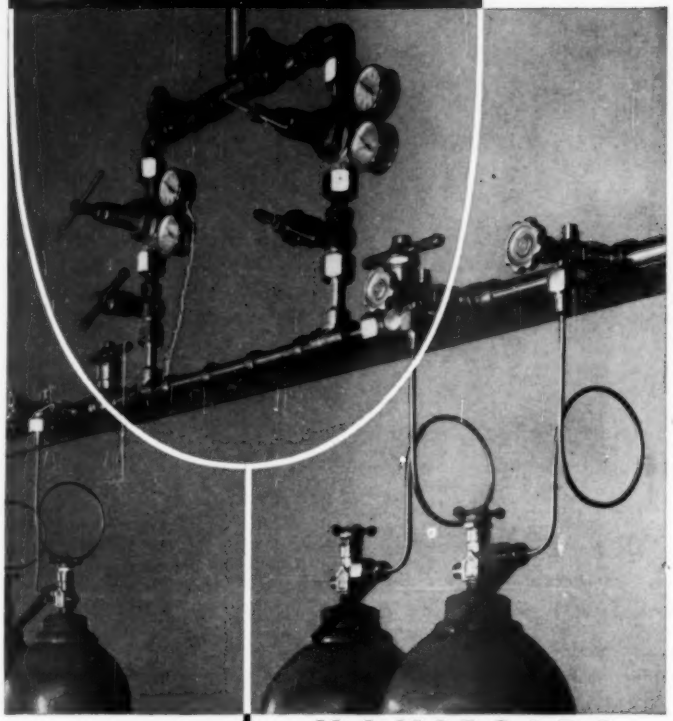
Nickel-Clad Stainless-Clad
Inconel-Clad Monel-Clad
STEELS

★

SOLID METAL ADVANTAGES WITH CLAD STEEL ECONOMY

• • SPEED SCRAP TO THE MILLS TO MAKE MORE STEEL • •

REGO*



MANIFOLDS

Rugged construction and precision control equipment give RegO manifolds long life, safe performance and low maintenance.

Continuous Operation . . . Shut-off valve at each cylinder station permits removal of any cylinder without shuting down entire side of manifold. Master valves control each bank of cylinders.

Unit Construction . . . Header consists of steel I-beam, extra heavy brass pipe and fittings, cylinder station and master shut-off valves . . . *with all permanent connections silver brazed.*

Precision Regulation . . . Uniform delivery pressure is assured by dual large capacity two-stage RegOlators.

for
OXYGEN
ACETYLENE
HYDROGEN
NITROGEN
and other high pressure gases

Write for 24 page catalog giving complete specifications.

*Reg. U.S. Pat. Office

The BASTIAN-BLESSING Company
4201 Peterson Ave. Chicago 30, Ill.

Pioneer and Leader in the Design and Manufacture of Precision Equipment for Using and Controlling High Pressure Gases

After the reading of the Resolutions prepared by these Committees, it was moved, seconded and unanimously adopted that these Resolutions be spread on the minutes of this meeting, be published in the SOCIETY'S JOURNAL, and that copies be transmitted to the families of the deceased members.

WRC Bulletin Series—Plan for Purchase and Resale

The Board voted approval of plan for the purchase and resale by A.W.S. of W.R.C. Bulletins.

Finances

Mr. Donald drew particular attention to exhibits showing that at the end of the first quarter of the current fiscal year, an excess expense over income of $5681.88 exists, as against an excess income over expense of $596.92, for the same period in the previous year. In the latter, at the end of the first quarter of the current fiscal year, our actual loss is $5681.88, against a budgeted loss for this period of $2213.93. Mr. Donald expressed the opinion that time is too short to draw conclusions as to our potentialities and the need for retrenchments. He prefers that the Board look for results of the efforts of the newly acquired advertising agent, Section activity and membership drive, during the next three months. At the close of the six months' period, the Finance Committee will make a careful study of the SOCIETY'S finances and offer recommendations to the Board.

Membership

Mr. Mooney, Secretary of the Membership Committee drew attention to the gains and losses during the first quarter of the current fiscal year, which resulted in a net gain of 185 members, and a total membership, as of Dec. 31, 1948, of 7578 members (121 Sustaining Members, 3143 Full Members, 4200 Associate Members, 105 Student Members and 9 Honorary Members). He made special mention of the loss of 9 members in the Sustaining classification.

Mr. Magrath reported that although the Sections have been slow in getting started on their membership drives, there is indication that many of them are now organized to carry on a vigorous campaign for new members and for regaining members who have let their membership lapse. He attributed loss of Sustaining Members possibly to the fact that the Board of Directors, last February, saw fit, as a measure of economy, to withdraw some of the Sustaining Member benefits, in particular, the bound volume of THE WELDING JOURNAL and the code service.

The Finance Committee was requested to give serious consideration to restoring some of the lost benefits to the Sustaining Member, in the light of our present financial condition, and with a view toward offering recommendation for reversal of action taken by the Board of Directors at its meeting last February, in respect to withdrawal of certain Sustaining Member benefits.

New MALLORY KO HOLDERS

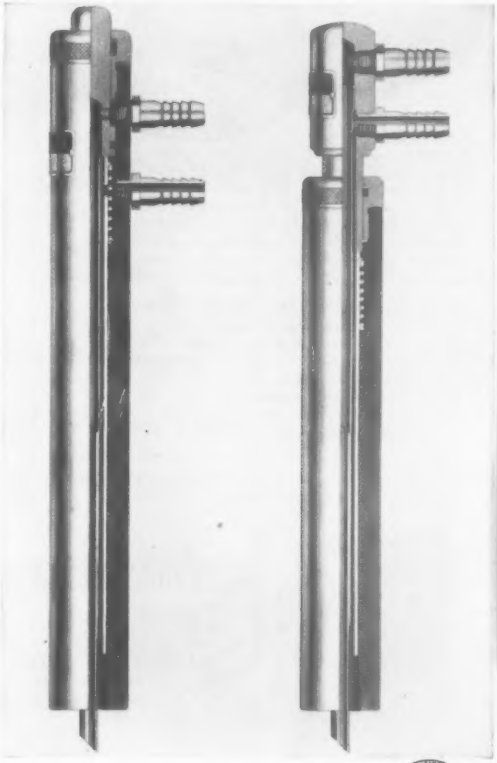
"K. O." Water Leaks!

Mallory does it again—makes welding history with a new line of leak-proof holders that offer two definite and major improvements:

1. *By using standard size O-Rings in place of ordinary packing, Mallory eliminates the problem of drops of water causing rust or discoloration of the material being processed.*
2. *The complete assembly—including all internal parts—is made of copper alloy, brass or stainless steel! This guarantees full water flow for the life of the unit, keeps the tip ejector mechanism free from any rust or corrosion that could interfere with its easy action.*

And Mallory proves it again before release to the industry. In laboratory tests, the ejector mechanism has been operated over 50,000 times—under water pressures far greater than encountered in normal usage! And KO Holders came through with flying colors!

It will pay you to investigate—*and prove to yourself*—the great advantages of the new Mallory leak-proof KO Holders. Write Mallory today.



In Canada, made and sold by Johnson, Matthey & Mallory, Ltd., 110 Industry St., Toronto 15, Ontario

RWMA

Resistance Welding Tips, Holders, Dies, Rod and Bars, Castings, Forgings

P. R. MALLORY & CO. Inc.

MALLORY

P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

SERVING INDUSTRY WITH

Capacitors — Rectifiers
Contacts — Switches
Controls — Vibrators
Power Supplies
Resistance Welding Materials

JUST BRING IN THE POWER LINES—
NO EXTRA EQUIPMENT NEEDED!

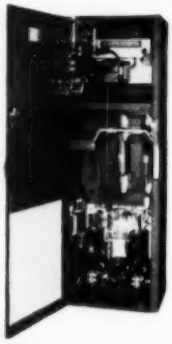
Weltronic Combinations

WITH BUILT-IN DISCONNECT SWITCH

These combinations are used where line short circuit protection is desired. The disconnect switch provides an easy means of disconnecting the welding machine from the supply lines. Simple compact installation is provided by combining the main line disconnect switch within the unit, making one integral complete factory wired package unit.

The cabinet houses either a NEMA 1A, 3B, or 5B timer, Ignitron contactor complete with surge suppressor and fusible disconnect switch. "PLUG-IN, SWING-OUT" timer construction permits change from NEMA 3B to 5B in less than 1 minute. Universal power supply operates from 208, 230, or 460 volts, 60 cycle source. Units for 380, 575 volts, or 25 cycle operation can be supplied.

Redesigned cabinets are for side of welder or wall mounting with interchangeable front or side mount of timer dials. Overall height is from 48" to 54".



STANDARD WELTRONIC FEATURES

1. Optional front or side mount of timer dials in the same cabinet.
2. Single unit combines timer and contactor completely interwired and ready to mount.
3. Exclusive Weltronic "Plug-In, Swing-Out" control panels permit change for NEMA 3B to 5B in less than one minute for timer conversion.
4. Universal power supply operates from all standard A. C. Services

WELTRONIC CO. 19500 WEST 8 MILE DETROIT 19, MICH.

WELTRONIC COMPANY
19500 WEST 8 MILE RD.
DETROIT 19, MICHIGAN

ATT. ADVERTISING DEPT.

Please send bulletin #11 WIM848 describing your Control Combinations with built-in disconnect switches.

NAME ..... TITLE .....

COMPANY .....

ADDRESS .....

CITY ..... ZONE ..... STATE .....

Report of Special A.W.S. Committee on Negotiations with A.S.M.

Mr. Weigel reminded the Board that, at its meeting on December 2nd last, the Special Committee rendered a progress report and was given authority to complete negotiations with A.S.M., providing an arrangement mutually satisfactory to both organizations could be effected. The revised agreement was submitted to Mr. Eisenman for acceptance. Mr. Eisenman has returned to A.W.S. Headquarters a signed copy of the agreement. The Committee now having completed negotiations mutually satisfactory to A.W.S. and A.S.M. asks acceptance of its report and the discharge of the Committee.

It was voted to accept the report of the Special Committee on A.W.S. negotiations with A.S.M. and to discharge, with thanks, the Special Committee.

Western Metal Congress

Mr. MacGuffie stated that he had received word from his Los Angeles representative that the program is nearly complete, and everything points to a successful meeting.

Specifications for Welding in Construction of Natural Gas Pipe Lines

Mr. Chyle stated his attention had been drawn to the need for specifications on applications of welding in the construction of natural gas pipe lines. It was stated that the A.P.I. has some information, and A.W.S. has a chapter in the 1942 edition of the *Welding Handbook* dealing with the subject. It was recommended that Mr. Barkow be requested to write the Technical Secretary of A.W.S., pointing out need for such specifications and suggesting scope and personnel for a committee.

Next Board Meeting

It was voted that the next meeting of the Board of Directors be held in the Statler Hotel, Cleveland, Ohio, on Friday, May 13, 1949, commencing at 9 A.M.

Change in Section Name

At a recent meeting of the Executive Committee of the Western New York Section of the AMERICAN WELDING SOCIETY, it was unanimously voted to change the name of the Section to the Niagara Frontier Section.

Careers in Engineering in Science

In a major contribution to guidance literature the Polytechnic Institute of Brooklyn is introducing an entirely new style of college publication entitled "Careers in Engineering and Science."

Representing a departure from the typical college catalog, the new career reference book has been edited with the primary aim of giving a simple and direct presentation of the opportunities available for professional training in an engineering college. Its main consideration is the point of view of the high school student and the adult leaders who work with young men.

What should interest young men plan-

PAGE *Welding* ELECTRODES AND GAS RODS

Welding Stainless? Costs too high?

ASK YOUR PAGE DISTRIBUTOR ABOUT:

Page *Allegheny Stainless Steel Electrodes and Gas Welding Rods*

Page *Range of Types*

Page *Field Service*

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. . . AND

ASK HIM ABOUT:

Page **PRICES!**

Prompt Delivery from Warehouses in Chicago, Denver, Philadelphia, San Francisco and the factory at Monessen, Pa.

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ning to become engineers and the lay public in general is the review in the publication of the tremendous battery of scientific instruments and facilities available in today's engineering college. From this standpoint, the book actually could be considered a survey of modern science as it applies to engineering. In fact, some of the experiments students must carry out in their courses are so advanced that they might make interesting stories as such in conjunction with an announcement of the publication.

Throughout its experience in counseling veterans, the Polytechnic faculty found a definite lack of literature on careers in engineering which gave an intimate picture of what constitutes the experiences of students in college. There are many books which explain what a civil engineer, an electrical engineer or a mechanical engineer does after graduation but none which tells of the actual experience a student will have in the four years of school while preparing for his profession.

In endeavoring at the outset to emphasize the importance of giving careful consideration to the choice of a career and to the selection of the college where the professional training may be taken, the handbook attempts to answer the questions "What are Engineering and Science" and "Who should study Engineering and Science."

Best Resistance Welding Papers to Receive $2250 in Prize Awards

Six prize awards totaling $2250 for the best papers on designing for, application of and research in resistance welding, submitted to the AMERICAN WELDING SOCIETY prior to August 1, 1949, have been announced by the Resistance Welder Manufacturers' Association.

Top prize of $750 will be awarded for the best paper from an industrial source dealing with such topics as redesign of a product for lower cost manufacture by resistance welding; Product improvement through use of resistance welding; Resistance welding research; Development of new procedures which broaden the usefulness of resistance welding; etc.

Authors of the second and third best papers in this category will be awarded prizes of $500 and $250 respectively.

The author of the best paper submitted by a University instructor, student or research fellow will receive a prize award of $300, with a $200 prize for the second best paper, from a University source, which in the opinion of the Board of Awards represent the greatest "original contributions to the advancement and use of resistance welding."

A new $250 prize for the best paper by an under graduate student has been added this year for the first time.

Anyone in the United States and Canada is eligible to compete for these prizes, the contest judges for which will be appointed by the AMERICAN WELDING SOCIETY. "Industrial sources" include not only manufacturing but also consulting engineering and laboratory organizations.

Copies of the simple rules governing the awards are available from the Resistance Welder Manufacturers' Assn., 505 Arch St., Philadelphia 6, Pa.

Resistance Welding Sales

1948 deliveries of resistance welding equipment to industry reported by member companies of the Resistance Welder Manufacturers' Association continued at the same high level as in 1947, close to 5 times total shipments during 1939, and 6 times the output for 1938, it was revealed here today by B. F. Wise, President of the Association.

At the same time, shipments of resistance welding electrodes—the yardstick of utilization of resistance welding—reached an all-time high during 1948, with an increase of approximately 20% over 1947. Comparative electrode figures for prewar years are not available since these have been reported to the Association only since April of 1946.

(*Continued on page 312*)

–this is worth buying!

WHEN you order Oakite Composition No. 61 or Oakite Aviation Cleaner or Oakite Compound No. 34 or Oakite Compound No. 84-A for preparing aluminum for welding —or Oakite Composition No. 70 for preventing adhesion of weld spatter on steel —you buy a lot more than drums of chemicals.

What you actually buy is *Oakite service*, which combines the knowledge gained in 40 years of chemical research with the practical engineering experience of more than 150 Oakite Technical Service Representatives working for tens of thousands of customers per year.

To discover the great value of *Oakite service*, phone the Oakite Technical Service Representative in your city or write to Oakite Products, Inc., 18E Thames St., New York 6, N. Y.

OAKITE 1909 1949 40th ANNIVERSARY YEAR

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INDUSTRIAL CLEANING MATERIALS • METHODS • SERVICE

Technical Service Representatives Located in Principal Cities of United States and Canada

for consistently good results use

BBB KEEN-ARC CARBONS

Designed to carry the high currents necessary for intense heat, BBB Keen-Arc Carbons produce a fine-grained weld of high tensile strength. They give a smooth, steady "flowing" flame which does not wander and which is concentrated at the desired focal point. Flame temperature is easily and accurately adjusted by merely changing the ampere input, and heavy copper coating permits gripping at extreme ends — eliminates frequent and periodic resetting.

A COMPLETE LINE OF CARBON WELDING SUPPLIES

In addition to Keen-Arcs, the BBB Line includes Carbon and Graphite Electrodes, Carbon Rods, Carbon Welding Paste and Welding Plates. Write for literature.

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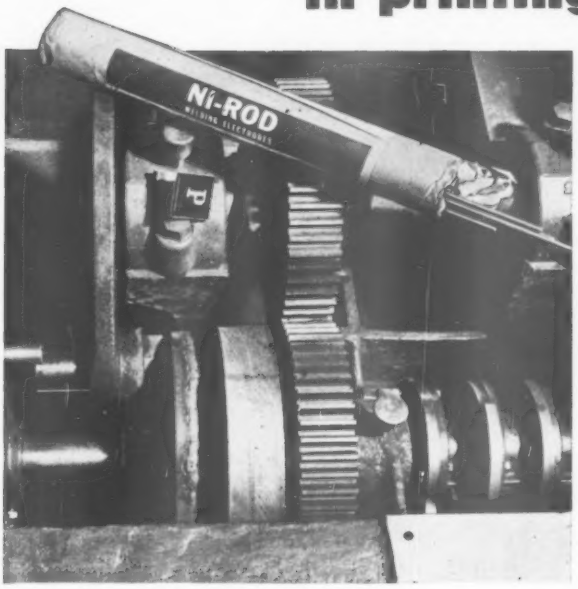
BECKER BROTHERS CARBON CO.

3450 SOUTH 52nd. AVE. CICERO 50, ILL.

Ni-Rod *Ventured* — Time and Money *Gained* in printing press repairs



A worn cast iron cam on this Miehle vertical press was built up with beads of NI-ROD without dismantling the gear box. The welder had no previous experience with metal arc welding.

This platen cam casting from a John Thompson press had two sections broken off. Both were restored by welding with NI-ROD.

RECENTLY, a firm that specializes in the repair and reconditioning of worn printing machinery took a gamble . . . a small one, but it paid handsome dividends.

Much of their repair work consisted of brazing and gas welding broken cast iron frames and worn machine members. So welding was an old story to them. *But* . . . they had never tried metal-arc welding.

Then they heard about the fine performance of Ni-Rod* electrodes in cast-iron maintenance work. They decided to give them a trial. Result? Today they use Ni-Rod for most of their welding work. And like thousands of other shops, they find that Ni-Rod saves both time and money: gives better results with less effort.

Ni-Rod gives sound, non-porous, *machinable* welds in all grades of cast iron. Slag removal is easy. Ni-Rod is stable-arcing in all positions with either AC or DC current. Preheating or post-heating is seldom necessary . . . an important time-saving feature. You can use Ni-Rod for joining cast iron to steel, too.

Why not try Ni-Rod in your own shop . . . soon? Discover for yourself why *4 out of 5* shops re-order Ni-Rod, once they've tried it.

Your nearest INCO distributor stocks Ni-Rod in 3/32", 1/8", 5/32" and 3/16" diameters.

Write for your copy of the helpful new 8-page booklet: "*NI-ROD . . . a new electrode for any cast iron welding.*"

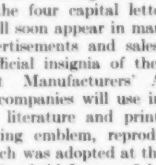
THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.

*Reg. U. S. Pat. Off.

NEWS OF THE INDUSTRY

American Weldment Manufacturers' Association

Printed in white against a dark background, the four capital letters "A.W.M.A." will soon appear in many publication advertisements and sales literature as the official insignia of the American Weldment Manufacturers' Association. Member companies will use in their advertising, literature and printed matter this striking emblem, reproduced herewith, which was adopted at the last business meeting held January 5th and 6th at the Hotel Moraine in Highland Park, Ill.



The present membership, most of whom were instrumental in forming the Association, now feel that their organization, having gone through its formative period and having developed plans and programs of real importance to the industry, can now well be enlarged to include representative members of the Weldment Industry throughout the United States and Canada. The present 16 member companies are confined to the Middle Eastern section, extending from Coatesville, Pa. to St. Louis, Mo. Any firm in the United States and Canada is eligible to join the Association provided that it does some outside welding in addition to its own production.

A new class of associate members has also been created. All individuals, firms or corporations who are suppliers or who are in some other way interested in the development and advancement of the weldment industry are eligible for nomination. This class of members will participate in all activities of the Association with the exception of voting and holding administrative offices which powers are reserved for regular members.

At the present time there are scheduled for the current year two more meetings of the A.W.M.A.—a general business meeting in April, the time and place to be announced at a later date and the annual fall meeting which will feature technical papers prepared by members and associates and other subjects pertinent to the Industry as a whole.

William C. Simpson, manager of sales for Lukenweld, Division of Lukens Steel Co., Coatesville, Pa., is president of A.W.M.A. for the current year. Other officers are: Hugh Hodges, manager of Weldment Division, Graver Tank & Mfg. Co., East Chicago, Ind., secretary; A. A. Fredrickson, vice-president of The Lakeside Bridge & Steel Co., Milwaukee, Wis., treasurer. These three officers constitute the executive committee of the Association.

The Board of Directors includes the above officers and the following members: Walter Koch, vice-president of International Steel Co., Evansville, Ind.; Sylvester Williams, manager of Weldment Division, Struthers Wells Co., Titusville, Pa.; Louis T. Kenney, vice-president of United Welding Co., Middletown, Ohio; and Charles Stewart, president of A. C. Woods & Co., Rockford, Ill.

In addition to the companies named above, membership now includes: American Welding & Engineering Co., Warren, Ohio; Berlin Chapman Co., Berlin, Wis.; Consolidated Welding and Engineering Co., Chicago; Dube Manufacturing Co., Chicago; Falk Corp., Milwaukee, Wis.; Pandjiris Weldment Co., St. Louis, Mo.; Optenberg Iron Works, Sheboygan, Wis.; Renner Mfg. Co., Milwaukee and Van Dorn Iron Works, Cleveland, Ohio.

The Byrne Marcellus Co., Chicago, has been appointed to act as management for the Association. R. D. Wisener, of Byrne Marcellus Co. is account executive handling A.W.M.A. activities. The general office of the American Weldment Manufacturers Association is located at 332 S. Michigan Ave., Chicago 4, Ill.

Several important activities were inaugurated at the recent meeting. One of these projects is the preparation and development of a booklet for sales promotion purposes. This booklet will be comprehensive as well as technically authentic (although written in nontechnical language) and aimed to dramatize the Weldment Industry. In print and picture, it will present a brief history of the Industry and outline its present scope and magnitude. Selected pictures of typical weldments will be reproduced, each accompanied by an explanation of why a weldment was used in preference to a forging, casting, stamping, etc.

The establishment of recommended standards and practices of weldment manufacturing is also on the A.W.M.A. program. These standards are expected to cover all phases of quality control such as steel specifications; standards of welding and weld sizes; over-all tolerances or any special or close tolerances; finishing by sand, steel grit or shot blasting; stress relieving; chipping and grinding; inspection including X-ray.

There also is being developed by the Association a cost manual which will present a statement of all essential elements of costing, together with recommended job costing procedure. This manual will set forth the best cost thinking and the best costing practices within the Industry, combined with counsel received from a recognized professional cost consultant. After the preliminary draft has been prepared, hearings will be held to which executive and cost personnel of member companies will be invited to discuss and revise the text. When the manual is finally published, an educational program will be carried out among A.W.M.A. members on the recommended cost program, though it is understood that adoption and use of the recommendations contained in the manual are to lie wholly within the discretion and individual judgment of each member.

The following committees and chairman have been appointed to implement these extensive projects:

1. *Manufacturing Standards and Practices:* W. G. Koch of International Steel Co., chairman; H. V. Williams of Struthers Wells Co.; R. J. Fisher of Falk Corp.; E. J. Charlton of Lukenweld; P. H. Setzler of United Welding Co.; A. K. Pandjiris of Pandjiris Weldment Co.; Dr. I. A. Oehler of American Welding & Engineering Co.

2. *Public Relations and Advertising:* Don W. Dawson of American Welding and Engineering Co., chairman: A. S. Fredrickson of Lakeside Bridge & Steel Co.; G. E. Stewart of A. C. Woods & Co.; H. D. Garber of Van Dorn Iron Works; and G. O. Renner of Renner Mfg. Company.

3. *Market Research:* N. T. Jones of Van Dorn Iron Works, chairman; M. R. Minnick of American Welding & Engineering Co.; A. S. Fredrickson of Lakeside Bridge & Steel Co.; and Geo. F. Linde of Dube Mfg. Co.

4. *Admission Standards:* L. T. Kinney, of United Welding Co., chairman; H. E. Hodges of Graver Tank & Mfg. Co.; M. H. Busse of Optenberg Iron Works; E. J. Carlton of Lukenweld; and John Gillett of Berlin Chapman Co.

The development of the A.W.M.A., as indicated by these far-reaching and basically sound plans and programs for the current year, is unquestionably evidence of the rapid and nation-wide growth of the Weldment Industry. Through its activities, the Association is providing and will increasingly provide the logical vehicle for the further development of the Weldment Industry as a whole.

Engineers' Day

All branches of engineering will be represented at the fifteenth annual Engineers' Day of the Colorado School of Mines in Golden, Apr. 22 and 23, 1949. The event will feature technical sessions in mining, metallurgy, petroleum production, petroleum refining, geophysics and geology, as well as exhibits from companies engaged in the mineral industries.

Results

Without Fuss or Noise

. . . that is why P&H "PF" electrodes are selected by welding experts to reduce costs on poor-fit work

The **6012 "PF"** electrode is a good one to have on your production team. Like any good team player, "PF" makes such easy work of irregular and poor-fit jobs that the low figures on your time sheets are almost unbelievable. With fast burn-off rate, "PF" operates quietly — there is no noisy fuss, bothersome sparks, or annoying spatter. This is the kind of efficiency you need in your shop — the kind of action that your welders appreciate; just ask them.

In addition to "PF's" quiet efficiency, experts also recognize the following features as important in keeping costs down:

Rapid solidification — It is the fast-setting characteristic of "PF" that makes it so excellent for all poor-fit-up work.

Fast performer — "PF" gets the work done in a hurry. Its ease of handling, and high deposition rate — the ability to withstand high welding current, low spatter, and easily-removed slag—all contribute to reduced time and lower costs.

Excellent for sheet metal also — "PF" is a good general-purpose rod that can be used in all positions. Not only is it superior for poor-fit-up work, but it also achieves excellent results on sheet metal.

Get out your toughest poor-fit problem and let a P&H representative or distributor show you how "PF" will save you time and money. Write us for literature.

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WELDING ELECTRODES
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Welding Positioners

AC Welders

Welding Production Control Systems

DC Welders

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THERMO
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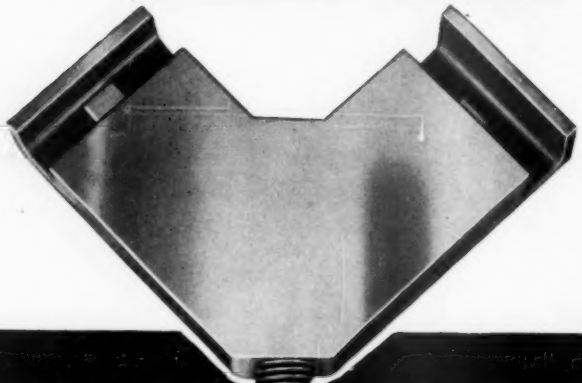
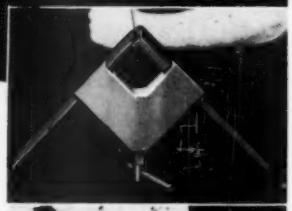
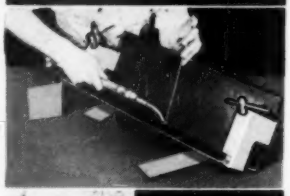


HOLDS 2 PIECES AT
EXACT 90° ANGLE





For quick, easy welding of two pieces of metal, of same or unequal thickness, at positively correct right angle.
No tacking necessary.
No steel square needed.
No special fixture needed.
Every welding and sheet metal shop should have Korner-Klamps.
Can more than save their cost on one job.
Save money, time and trouble by asking your welding supply dealer for Korner-Klamps.

Only
$6.75

THERMACOTE COMPANY
Newark Chicago Los Angeles Portland

Licensing Agreements for Powder Scarfing and Powder Cutting

The Linde Air Products Co., a unit of Union Carbide and Carbon Corp., has widely licensed its Powder-Scarfing and Powder Cutting Processes to industry for conditioning and fabricating stainless steels and other metals normally resistant to oxygen cutting.

Linde now offers to grant licenses on its Power Scarfing and Power Cutting Processes to any commercial oxygen producer, to any manufacturer of oxyacetylene equipment and supplies or to anyone who may have a legitimate interest in extending the economic benefits of these processes to industry. Licenses are granted under the process claims of Linde's Power Scarfing and Powder Cutting Patent rights upon reasonable and uniform terms and include the right to sublicense.

Victor Handles Stud Welding

Appointment of Victor Equipment Co., San Francisco, as exclusive distributors for Nelson stud-welding equipment and products in the Pacific Coast area has been announced by Leonard C. Barr, vice-president of Morton Gregory Corp. and general sales manager of its Nelson Stud Welding Division, Lorain, Ohio.

The distributorship, effective February 1st, will cover both sale and rental of Nelson stud-welding guns and control units, and sale of Nelson flux-filled studs and other fasteners in the states of California, Oregon, Washington, Nevada and Idaho.

L. W. Stettner, president of Victor Equipment, commenting on the arrangement, pointed out that the company's seven branches, from Seattle on the north to San Diego on the south, will be in an ideal position to render prompt service to manufacturers, shipbuilders and construction industries where adoption of stud welding has proved profitable. He said Victor will carry a substantial inventory of stud welding equipment and standard M-G studs for immediate delivery.

Stud Welding Equipment

Nelson stud-welding equipment can now be obtained on a rental basis, according to an announcement made by Leonard C. Barr, vice-president and general sales manager of the Nelson Stud Welding Division of Morton Gregory Corp., Lorain, Ohio.

Heretofore available only through purchase, the lightweight stud-welding gun, automatic control unit and necessary welding cables can now be obtained for a fixed monthly rental of $45.

The rental policy has been inaugurated in response to requests from contractors who have been using stud welding for the erection of roofing, siding and form work and for the installation of piping, insulation, electrical and other facilities.

Equipment can be obtained in principal cities through Nelson field engineers who are available for demonstrations and instruction of personnel operations.

ALL STAINLESS AND HEAT RESISTING ARC WELDING ELECTRODES STOCKED. ALSO ELECTRODES TO MEET SPECIFIC ANALYSES. COMPLETE FACILITIES FOR COLD DRAWING, ROLLING, PICKLING AND ANNEALING

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Conservation Symposium

The Engineers Council of Houston announced its second annual Symposium to be held at the Rice Hotel, Houston, Tex., Saturday, Apr. 2, 1949.

The Symposium will be on the subject, "The Conservation of Our National Resources." Five papers on the major phases of conservation will be presented by nationally prominent authorities.

Ohio Welding Conference

The tenth meeting of the Ohio Welding Conference will take place on the Ohio State University campus April 7th and 8th as part of the university's 75th anniversary observance.

Ohio State's department of welding engineering in cooperation with the Cleveland, Columbus and Dayton sections of the AMERICAN WELDING SOCIETY, will sponsor the conference.

Each half-day of the program will center on a different phase of the welding field, with topics scheduled as follows:

Thursday morning, April 7th—oxy-acetylene welding and inert-gas shielding; Thursday afternoon—applications of metallic arc welding; Friday morning, April 8th—resistance welding; and Friday afternoon—power piping and pressure vessel work.

Speakers will include C. B. Voldrich, Chief Welding Engineer, Battelle Memorial Institute, Columbus; M. I. Banash, consulting engineer, Chicago; Martin Korn, consulting engineer, Detroit; Adrian Busick, Chief Engineer, Marion Power Shovel Co.; and F. A. Bodenheim, Jr., The Federal Machine and Welder Co., Warren, Ohio.

The Columbus section of the AMERICAN WELDING SOCIETY will be host at a conference dinner the evening of April 7th. Speaker will be O. B. J. Fraser, first vice-president of the A.W.S. and Director of Technical Service on Mill Products, International Nickel Co., New York City.

Further details on the meeting may be obtained from the Department of Welding Engineering, Ohio State University, Columbus 10, Ohio.

Industry Going Ahead

An indication that industry recovered rapidly from the surprise of the November election is indicated by figures just released by the Resistance Welder Manufacturer's Association.

Orders for new resistance welding equipment placed with member companies of the Association in December showed a gain of better than 80% over November totals, according to B. F. Wise, President of the Trade Assn. In addition, Mr. Wise points out, cancellation of orders placed prior to the November election which totaled almost 15% of new equipment orders, in November, dropped off in December to less than 1% of new business—actually below the normal monthly average.

"When these two factors—a sharp increase in orders for equipment, accompanied by a sharp decline in cancellations — are taken together," Mr. Wise points out, "the outlook for the future months is quite promising. We are looking for a further healthy gain in sales of resistance-welding equipment as retail prices exert more and more of an influence over the sales totals for all kinds of manufactured products."

Included in the increased business of member companies during December was a sizeable increase in foreign orders, reaching a new peak for the year. While foreign business still represents a relatively small proportion of the total, Mr. Wise points out that a continuation of the present trend may result in making foreign business a sizeable factor in the sale of resistance welding equipment. On top of an 11% increase in November over the totals for the entire 3rd quarter, December showed a further gain of 170% over November foreign sales totals.

Aluminum Association Elects Officers at Annual Meeting

At the annual meeting of The Aluminum Assn. held January 18th to 20th in New York, R. S. Reynolds, Jr., of the Reynolds Metals Co., Richmond, Va., was elected president for the ensuing year. The following were elected vice-presidents: E. G. Grundstrom, Advance Aluminum Castings Corp., Chicago; M. E. Rosenthal, United Smelting and Aluminum Co., Inc., New Haven, Conn.; and George N. Wright, The John Harsch Bronze and Foundry Co., Cleveland. A. V. Davis, Aluminum Company of America, New York, was re-elected chairman of the board, and Donald M. White was re-appointed secretary and treasurer.

Three directors-at-large were elected to serve for three-year terms: Frank B. Cuff, Aluminum Company of America, New York; R. G. Farrell, New York, of Fairmont (W. Va.) Aluminum Co., who has just completed two terms as president of the Association; and W. A. Singer, Apex Smelting Co., Chicago.

The Association's foundry, extrusion and sheet divisions also held sessions during the three-day meeting. George N. Wright, The John Harsch Bronze and Foundry Co., Cleveland, was re-elected chairman of the foundry division, and H. J. Hater, of Aluminum Industries, Inc., Cincinnati, was appointed to represent the division on the Association's board of directors. In the sheet division, L. M. Brile of Fairmont Aluminum Co., Fairmont, W. Va., was re-elected Chairman, and George M. Carter, of the Sheet Aluminum Corp., Jackson, Mich., was named to represent the division again on the board of directors. Harold C. Wilson, Revere Copper and Brass, Inc., Baltimore, Md., was re-elected chairman of the extrusion division and reappointed the division's representative on the board of directors.

Member companies of The Aluminum Assn. account for all the primary aluminum production in the United States and about 85% of aluminum semifabricated products.

75th Anniversary

Herman Welzien, in his 58th year of service with A. O. Smith Corp. of Milwaukee, Wis., lights the candles on the 75th birthday cake of the Corporation, as J. J. Stamm, Treasurer, in his 51st year of service, looks on.

The A. O. Smith Corp. was founded as a general machine shop in a semibasement in downtown Milwaukee in 1874 by C. J. Smith and his sons. It specialized in frames and other parts, first for baby buggies, then for bicycles.

Buy "PROVEN FLUXES"
Years of GUARANTEED SATISFACTION behind these GOOD
"ANTI-BORAX" FLUXES
Insist on them — Unequalled Quality

No. 1 Cast Iron Welding Flux
No. 2 Brazing Flux for Brass, Bronze, Steel, etc.
No. 4 Braz-Cast Flux for Bronze Welding Cast Iron
No. 5 & 8 Cast & Sheet Aluminum Fluxes
No. 9 Stainless Steel Welding Flux
No. 11 Tinning Compound
No. 16 Silver Solder Paste Flux

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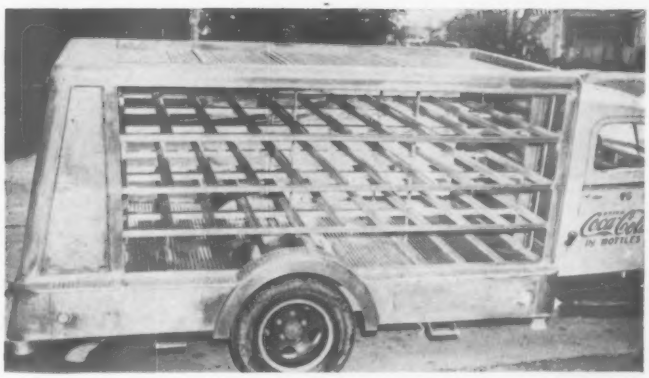

In 1902 Arthur O. Smith, one of the sons, produced the first pressed steel auto frame, and in 1904 the firm took his name.

When A. O. Smith died, in 1913, and was succeeded by his son, L. R. Smith, the firm had become the world's largest maker of auto frames.

Built on the knowledge of working steel developed in the frame business, and a unique understanding of welding which stemmed from the mass production of aerial bombs during World War I, The A. O. Smith Corp. successively began, and subsequently became a leader in, the manufacture of welding electrodes, pressure vessels, large diameter gas line pipe and oil well casing, single-piece glass lined tanks for beer storage, domestic and large volume water heaters, electric motors, petroleum meters and vertical turbine pumps.

All-Welded Aluminum Bottler's Truck Body

An all-welded, all-aluminum bottler's truck body, reportedly the first of its type ever produced, was recently manufactured by the Lerio Corp. of Mobile, Ala., using General Electric inert-arc welding equipment. Weighing approximately half as much as a conventional steel model of comparable size and capacity, the new beverage carrier was produced using a G-E 200-amp., a.-c. inert-arc welder, a machine specifically developed for the welding of aluminum, magnesium, stainless steel and kindred metals without oxidization or discoloration.

"At first," a Lerio engineer said, "we were skeptical of the advisability of such a project. We couldn't get the proper shapes of aluminum, both riveting and gas welding were impractical for this application, and the cost to the consumer would be very high." However, he pointed out, after discussing the problem with a group of welding, metal fabricating, and construction engineers, the design and production techniques were decided upon and the truck produced.

The purchaser of the new truck, the Mobile Coca-Cola Bottling Co., has been using it constantly for the past few months and checking its performance. The company reported that, despite the normal rough handling which a beverage carrier is called upon to take in everyday usage, no structural defects have been detected, thus proving the feasibility of the all-welded aluminum construction.

Circular Welds on Curved Surface

A midwestern manufacturer is using the equipment shown to join a smoke pipe collar to the radiator shell of a hot air furnace. This 10-in. diameter weld is made in approximately 40 sec. by a Unionmelt UE welding head attached to the arm of a shape-following carriage. An adjustable radius bar guides the tracing head in a circle of the proper diameter. Even though the weld lies on the curved surface of the larger piece, the electronic voltage control takes care of this vertical difference by regulating the rate of rod feed.

It takes only a few minutes to remove the radius bar attachment and change the tracing head to follow a strip templet. The oval templet in back of the machine is used for shape-welding another part of the furnace.

The use of a shape-following carriage makes it possible to obtain the advantages of the Unionmelt process when welding practically any desired outline.

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"Eutectic Low Temperature Weldrods" can solve it for you the modern way by joining metals at low heat — avoiding distortion, stress, warping, overheating.

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AIR OIL, and WATER COOLED.
Sizes 1/4 to 300 KVA.

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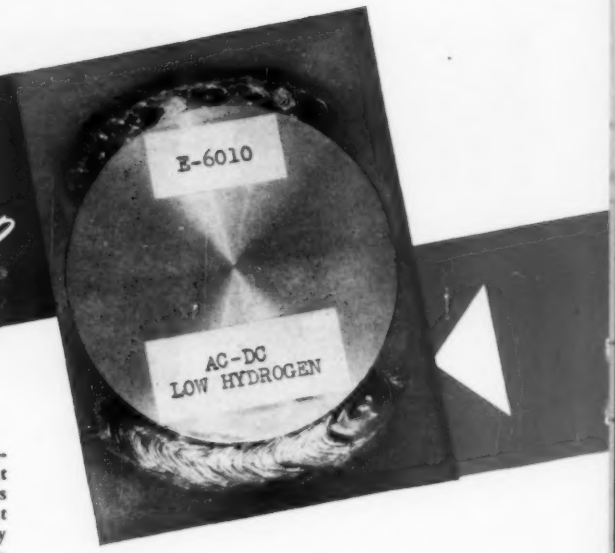
Welding Hardenable or Sulphur-bearing Steels?



1. Fewer structural failures from underbead cracking—Ordinary electrodes deposit a large amount of hydrogen in weldments on hardenable steel. This produces underbead fissures *not* generally apparent in routine inspection, which in turn causes early structural failures in service. General Electric *low-hydrogen* rods have a special coating which materially reduces the amount of hydrogen deposited, thereby largely eliminating the basic cause for such failures.

2. Better mechanical properties—Laboratory comparisons between these low-hydrogen electrodes and class E6010 electrodes show the former to possess higher tensile and yield strength, better elongation, and *higher impact* at both room and sub-zero temperatures.

3. Welds can be successfully enameled without heat treatment—as has been actively demonstrated on both a laboratory and production basis.

4. Materially improved operating characteristics—G-E low-hydrogen electrodes are extremely flexible in application, with either a-c or reverse polarity d-c; spatter is minimized, deposition efficiency is high, penetration is adequate but not excessive. There is little or no tendency for surface holes to occur in metals of relatively high sulphur content—and in all cases the finished weld offers an excellent appearance. (Note lower bead in photo above.)

THESE ARE THE G-E "LOW-HY FAMILY"

W-32 is the "father" of the line, having been offered since 1945. A new, greatly improved version was recently introduced—and this performance-proved electrode is now listed at a new, attractive price.

W-60, W-61, W-62 are three brand new additions, with recommended applications as follows:

W-60—For welding hardenable steels where hazards of underbead cracking are to be eliminated.

W-61—For a wide variety of low-alloy, "high-tensile" steels.

W-62—For use on steel castings and for producing weld deposits having high impact properties at subzero temperatures.

AND THESE OTHER G-E ELECTRODES CAN DO AS MUCH FOR OTHER WELDING JOBS

Mild-Steel and General-Purpose Electrodes—This group of 9 types is headed by W-28, a new general-purpose, all-position rod with an unusually stable arc that produces welds of superior appearance, at high speeds, with minimum convexity. Other electrodes in this group are available specifically for horizontal, vertical, or over-head welding, etc.

Stainless Steel Electrodes—27 types (16 for d-c, and 11 for a-c or d-c) make this one of the most complete stainless lines available. Each type is keyed to specific AISI code numbers for easy selection. Special, double-carton packaging protects the rod against moisture as well as providing extra protection against transit and storage damage.

Cast-Iron, Hard-Surfacing, & Phosphor-Bronze Electrodes—Herein are some of the more recent additions to the G-E electrode line; W-2075 for making machinable welds on cast-iron; W-94 for abrasion-resistant, hard-surfacing applications; and W-70 for phosphor-bronze welding. They are exemplary of G. E.'s welding laboratories' constant search for better electrodes, improved equipment, and more efficient welding processes.

HERE'S WHY G-E LOW-HYDROGEN ELECTRODES WILL MEAN MONEY IN YOUR POCKET

HERE'S WHAT USERS FIND WITH G-E "LOW-HY" ELECTRODES

Production had virtually stopped at a Pennsylvania machinery manufacturer's plant because cracks were developing in weld-fabricated steel parts. A rush shipment of W-32 from our Philadelphia distributor eliminated the cracking and had them back in production the same afternoon.

Arc welding in general and W-32 electrode in particular played an important part in fabricating this ram or slide for a 200-ton, straight-side crank press. Welded construction with W-32 was used extensively throughout the entire press.

A mid-western transformer manufacturer now swears by W-32 after finding that it completely eliminated a severe cracking and porosity problem in the fabrication of transformer tanks.

You can order these low-hydrogen electrodes from your G-E Arc-welding Distributor today. And ask him for your copy of the new pocket-sized electrode catalog, GES-3571. ***Apparatus Department, General Electric Company, Schenectady 5, N. Y.***

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"A-C or D-C . . . there's G-E Arc-welding Equipment for Every Application!"

ARC WELDERS • ELECTRODES • ACCESSORIES

GENERAL ELECTRIC

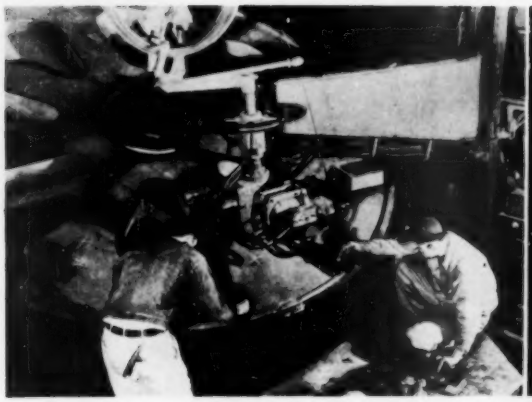


Fig. 1 One of two large bull gear wheels to drive a ship's propeller shaft is shown in the welding shop of the Westinghouse Electric Corp.'s plant at Sunnyvale, Calif. The wheel turns slowly under the Unionmelt welding machine as the hub is being welded to the centerpiece

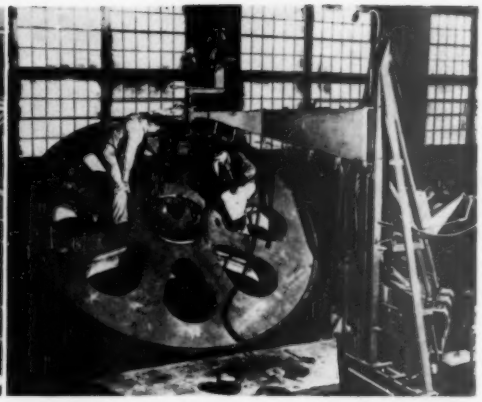


Fig. 2 The worker at right keeps constant check on adjustment of the welding apparatus. The man at the left is removing excess flux with a suction hose. Hidden by the welding machine wheel are the torches that keep the rim heated during the weld

Welding Marine Bull Gear

The Welding Marine Bull Gear, weighing 7½ tons, fabricated at the Sunnyvale, California Works of Westinghouse Electric Corp., is one of two similar gears to drive a large, marine ore carrier. The two gears are in the final stage of a series of gears taking the full load of a 7000-hp. marine turbine propulsion unit and reducing the speed from 6000 to 100 rpm. for the propeller shaft.

The hub is being welded to the centerpiece that forms one side of the wheel in Fig. 1. Flux is fed automatically as the wheel turns slowly under the welding machine. In Fig. 2 the rim is being welded to the wheel.

Two kinds of steel go into this bull gear wheel. The rim is of high-carbon steel to be hobbed later into 693 helical teeth that must later withstand great pressures under continuous operation. The remainder—hub, centerplates and ribs—is made from mild or medium-carbon steel.

Despite its size and ruggedness, each bull gear must be made to extremely close tolerances for such massive equipment. When completed and installed in a ship, they must operate trouble free for many years. Since the slightest inaccuracy in the gear teeth will cause excessive vibration and noise in the ship, inspection is rigid. Any imperfection, however small, will cause rejection. Tolerances for the helical teeth cut in the rim are as close as one ten-thousandth of an inch.

Counterstress and Special Fixtures Speed up Welded Construction

The use of counterstress or prebending to balance warpage caused by welding has eliminated the need for straightening of welded parts at the Frank G. Hough Co. of Libertyville, Ill. Also, special fixtures have been designed to make the greater portion of the work at the Hough Co. flat welding; careful positioning minimizing the necessity for vertical or overhead welds. These features according to T. Seals, Welding Foreman, have increased production by expediting the welded construction of the tractors, shovels, front-end loaders and other road building and materials handling equipment produced by this company.

Twenty General Electric welding units, ranging from 300 to 500 amp., are used by the 50 welders employed by the concern. Welding plays a part so important in the manufacture of the Hough apparatus that almost every component of their machines passes through the welding booth at some time before it reaches the assembly stage. The welded construction must be exceptionally strong because it has to withstand the heavy-duty work and severe handling that the Hough machines are subjected to in everyday use; in loading, hauling, road building, earth moving and materials handling.

The smallest of the wide variety of parts welded by this company is a tiny ⅜-in. nut which fastens to an accelerator bracket, and the largest single welded part is the main frame of a giant tractor-loader. Two men work simultaneously on this huge loader, and more than 60 lb. of General Electric Type W28 electrode goes into its construction.

The Hough Co. also fabricates tractor shovels and front-end loaders for industrial wheel-type and crawler tractors.

NEW LITERATURE

Specifications Booklet

The Tentative Specifications booklet for "Copper and Copper-Alloy Metal Arc Welding Electrodes" issued jointly by A.W.S. and A.S.T.M. is now available. It covers A.S.T.M. Designation B 225-48T and A.W.S. Designation A 5.6-48T in ten pages and the cover is in the convenient 6 x 9 in. size. Obtain your copy by writing Ampco Metal, Inc., Dept. W. S., 1745 S. 38 St., Milwaukee 4, Wis.

Hard Surfacing Weldirectory

The Lincoln Electric Co., Cleveland 1, Ohio, has issued an important technical bulletin 466 entitled, *Lincoln Weldirectory for Hard Surfacing*. This bulletin contains theoretical and practical information on arc-weld surfacing. It includes a guide for the selection of Lincoln electrodes and then describes in detail the properties and applications of each of the numerous Lincoln hard-surfacing electrodes.

Spot-weld Radiography

Copies of paper entitled, "Short Source-Object Distance Exposure Techniques in Spotweld Radiography," by R. C. McMaster, F. C. Lindvall and J. W. Smith of the Battelle Memorial Institute, Columbus, Ohio, have been reprinted from *Nondestructive Testing*, VI, No. 2, Fall, 1947. Copies of this reprint are available through the Battelle Memorial Institute, Columbus, Ohio.

The Measurement of Stress and Strain in Solids

The book, *The Measurement of Stress and Strain in Solids*, is based on the Proceedings of a Conference arranged by the Manchester and District Branch of the Institute of Physics. It includes a Foreword by Prof. D. R. Hartree and twelve special lectures covering wire resistance strain gages and their use; a review of some of the recent developments in photo elasticity; a review of some of the strain measuring devices; the measurement of strains in metals by X-rays; the use of X-rays for investigation of residual stress in ship structures and a note on acoustic strain gages.

Bound in cloth. 130 pages, 41 illustrations. Price in United States $4.00, including postage and packing. Printed in Great Britain. The Institute of Physics, 47, Belgrave Square, London, S.W. 1, England.

New Booklet on Galvanic Cell Corrosion

Reasons for galvanic cell corrosion, as well as methods for helping to overcome it, are contained in a new booklet issued by The International Nickel Co.'s Corrosion Engineering Section.

The booklet is complete in all engineering details and includes drawings and other essential illustrative material. Its 7½ pages are designed to provide the production man as well as the engineer with brief but informative material, based on more than forty years of study into this and other phases of corrosion.

It is available without cost from The International Nickel Co., Inc., New York 5, N. Y.

Diesel Locomotive Maintenance Welding

The Air Reduction Sales Co. has announced the availability of a reprint entitled, "Diesel Locomotive Maintenance Welding," written by R. L. Rex, Airco's General Superintendent of Railroad Service.

The article was originally presented in the form of a paper before the 29th Annual Meeting of the AMERICAN WELDING SOCIETY and subsequently appeared in THE WELDING JOURNAL.

The 12-page reprint is illustrated with 23 photographs and covers such maintenance operations as rebuilding diesel locomotives, repair of engine bases, reclaiming aluminum pistons and welding cast-iron cylinder heads.

For a free copy of this reprint, write the Airco office nearest you, or Air Reduction Sales Co., 60 E. 42nd St., New York 17, N. Y.

Training Distributors' Salesmen

One of the most baffling problems confronting the Welding Supply Distributors today is the constant need for written product knowledge from manufacturers, about the products they handle. To meet this gap between manufacturer, distributor and his salesmen, Eutectic Welding Alloys Corp., New York, manufacturers of low-heat arc- and gas-welding rods, Welding equipment and fluxes, announces a new policy of monthly distribution of a unique publication called *Eutecrod-of-the-Month*.

Rene D. Wasserman, President, offers this 16-page booklet as the answer to the increasing need of every welding supply distributor, salesmen and countermen, to familiarize himself with technological advantages, applications and properties of Eutectic low-heat welding rods. Mr. Wasserman plans to issue this brochure in monthly installments. The first issue deals with Eutectrode 24/49, the welding electrode for "cold" arc welding of cast iron and over 1000 have already been mailed to distributors all over the country.

Plans are underway to issue twelve consecutive Eutecrod - of - the - Month Courses covering different Eutectic low-heat welding alloys for the coming year.

Cathode Press

The Machlett Laboratories, Inc., Springdale, Conn., has issued a Review Issue dated December 1948. This issue covers the latest developments of this company in X-ray tubes, several of which are used in the examination of welds. Copy available upon request.

Hard Facing Dies

Just published, a four page booklet describing the hard facing of forming and drawing dies.

Life of dies can be increased from 5 to 30 times by hardfacing them as described in the booklet.

Complete procedures are outlined with three alloys available for different size dies. Steps in preparing and overlaying the dies are given.

Copies available from Wall Colmonoy Corp., 19345 John R Detroit 3, Mich.

Employment Service Bulletin

Positions Vacant

V-233. Position available. Recent engineering graduate with some industrial or field experience to teach welding at a leading Pacific Coast University.

Services Available

A-568. Welding Engineer. 35 years of age. Experience in light and heavy gage materials including mild steels, alloy and stainless steels and aluminum. Wide experience in welded design, job planning and developing production setups. Also handled testing, inspection and supervision. Desiring cooperation with a large manufacturing company of pressure vessels to U.S.A. or Welding-Consulting of an American Rods Mfg. Co., in principal district office to Brazil.

A-569. Veteran. Age 27. Married. Approximately five years practical welding experience on ferrous and non-ferrous alloys. Familiar with codes, testing, and inspection methods. Desire permanent position where past experience, education, and ambition may be fully utilized. Location immaterial but prefer West. To receive B.S. Met. E. in June from prominent Eastern university. Scholastic record and reference on request.

PERSONNEL

OBITUARY

H. W. Sweet

Howard W. Sweet died in the Mayo Clinic at Rochester, Minn., on Friday afternoon, December 10th, at 1:30 P.M. He was President of Purity Cylinder Gases, Inc., with general offices at Grand Rapids and branches at Kalamazoo, Lansing, Benton Harbor, Michigan and Warsaw, Ind. Mr. Sweet was well known to this industry. He was born on his father's farm adjacent to Hudsonville, a suburb of Grand Rapids, and grew up in the compressed gas industry, entering the employment of the old Grand Rapids Welding Supply Co. in 1930, with which company he continued to be associated until he became General Manager of Kwik-Gas Corp. of Hudsonville, Mich., which was the first independent bottled gas company established in that state.

In 1937 he and his associates, Edward Butterfield and Glenn G. Garman, formed Purity Cylinder Gases, Inc., at which time he was elected President, and continued in that office until his passing.

He was a member of Compressed Gas Manufs.' Assn., AMERICAN WELDING SOCIETY and Liquefied Petroleum Gas Assn., Inc. He had served on several active committees of LPGA.

He is survived by his wife, Jane, and his daughters Jane and Candice.

Wise Elected President R.W.M.A.

B. L. Wise, Director of Production, National Electric Welding Machines Co., Bay City, Mich., has been elected President of the Resistance Welder Manufacturers' Assn. at the Association's annual meeting in Detroit. Mr. Wise succeeds T. S. Long, Vice-President and General Manager, Taylor-Winfield Corp., Warren, Ohio, who was elected Chairman of the Executive Committee.

Named Vice-President of the group, which comprises manufacturers of resistance welding equipment was T. Embury Jones, President, Precision Welder and Machine Co., Cincinnati, Ohio.

The "alloy" group in the association, comprising manufacturers of resistance welding electrodes, etc., elected as its Chairman, W. G. Fetter, Manager, Resistance Welding Div., P. R. Mallory & Co., Inc., Indianapolis.

George A. Fernley and H. R. Rinehart were re-elected Executive Secretary and Secretary-Treasurer, respectively. Fernley and Rinehart make their headquarters at the Association's main offices at 505 Arch St., Philadelphia, Pa.

Sweeney Made Sales Manager

Harry D. Sweeney has been appointed Sales Manager of Welding Products for the American Manganese Steel Div., American Brake Shoe Co., according to an announcement by W. M. Black, Division President. He formerly held the position of Sales Engineer.

Mr. Sweeney has been with Brake Shoe since 1945. A native of Harvey, Ill., he was formerly associated with the Acme Steel Co. During World War II he served as a First Lieutenant with the U. S. Army in England and France. He will continue to be located at the Division's headquarters in Chicago Heights, Ill.

Deily Joins Arcway Equipment

Richard L. Deily is a graduate of Lehigh University with the Class of 1934, and has a Bachelor of Arts degree. He went with the Bethlehem Steel Co. at Bethlehem in 1936, and remained there until he left to come with Arcway Equipment Co. He became the District Manager for Arcway Equipment Co.'s Pittsburgh office on February 1st.

Mr. Deily was with the Bethlehem Steel Co. in various departments. He worked two years in the Metallurgical Laboratory testing and reporting on project activities. For five years, he was Assistant Welding Supervisor in charge of training weldors, developing new welding methods, and

supervising welding work. For two years, he was Development Engineer in Heavy Forging Mfg. Div., solving problems in the manufacture of ordinance equipment. For two years he was Welding Engineer in the Development Dept. applying new welding methods in various plants of the Bethlehem Steel Co., and also acting as liason between welding suppliers and the Bethlehem Steel Co. Also he acted as liason between the Bethlehem Steel Co. and their customers on welding.

During the last year he spent his time in the Weldment Products Dept. developing new methods of manufacture and welding. During that time he was active in various sectional activities.

B. L. Wise *T. S. Long* *T. Embury Jones*

POPULARIZING THE WELDING JOURNAL

The Publication Committee has instructed the Editor to add a special section in The Welding Journal each month, under some departmental heading as "Practical Welder and Designer." The nucleus of this special section will be one article each month of not more than four pages nor less than two which will give practical information on how to do a specific job, covering as many of the following topics as possible:

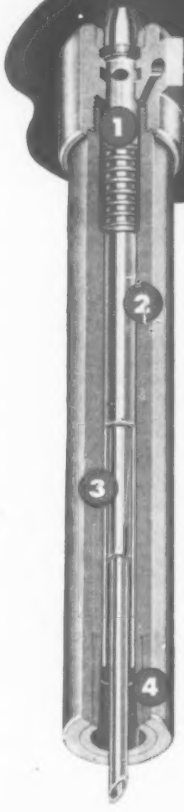
1. An exact procedure with illustrations of how to do the job.
2. Detail information as to design.
3. Full information on welding procedure or fabrication details.
4. Testing and inspection.

The Publication Committee has set aside $50 each month for payment of accepted articles of this nature. They should be written preferably by one who has followed the specific application in detail. Clear photographs or charts will be helpful and should be utilized.

WEIGER-WEED TRADE MARK

the holder designed as a perfect corollary to this well-known formula . . .

$H = I^2 R$



For complete line of WW quality welding supplies consult Weiger-Weed Bulletin 14.650. Send for it.

Weiger-Weed Electrode Holders can deliver more than enough cooling water for any resistance welding application using replaceable tips—without a sign of a leak! They are most dependable for long service, reduction of tip damage, down time and maintenance.

Quality to the same high standards is found in Weiger-Weed replaceable tips, seam welding wheels, projection welding dies, flash and butt welding dies and special alloy bars, forgings and castings. You are cordially invited to bring your resistance welding problems to Weiger-Weed. Long specialized welding engineering experience and every modern facility are at your service. Weiger Weed & Company, Division of Fansteel Metallurgical Corporation, 11644 Cloverdale Ave., Detroit 4, Michigan.

1 Hardened stainless steel knockout plug, and leak-proof water seal. Spring return assures free water ports and proper tip seating.

2 Non-rusting non-magnetic knockout tube.

3 Strong heavy body assures maximum conductivity, withstands heavy clamping pressure.

4 Hard alloy taper socket will not get out of round nor leak.

WEIGER-WEED TRADE MARK

11504-B

Resistance Welding ELECTRODES

DIES • TIPS • WHEELS • HOLDERS

DIVISION OF FANSTEEL METALLURGICAL CORPORATION

He has been active in the American Society for Metals, and Chairman of the Lehigh Chapter.

He was largely responsible for starting the Lehigh Section of the AMERICAN WELDING SOCIETY, and was elected one of the Officers. He is a Member of the AMERICAN WELDING SOCIETY, the A.S.M. and the American Association for the Advancement of Science. He is also a member of the AMERICAN WELDING SOCIETY Handbook Committee on Oxygen Cutting. In addition, he taught for many years the adult education in metallurgy and welding in Bethlehem.

Zucker Joins Precision Welder

Myron Zucker, Engineering Co. of Detroit, has been named representative in southeast Michigan and Toledo for Precision Welder and Machine Co., Cincinnati, Ohio, manufacturers of resistance welding equipment.

Mr. Zucker brings to his new position wide experience in electrical and welding engineering, having been with Detroit Edison on power supply for welders and Nackworth G. Rees, Inc., in the developing and applying portable gun welder cables.

An Electrical Engineering graduate of Cornell and Union as well as the General Electric Co. Engineer Training Course, Mr. Zucker is Chairman of the Michigan Section Welding Group of A.I.E.E., Vice-Chairman of the A.I.E.E. National Welding Committee, Engineering Society of Detroit and Electrical Association of Detroit.

Myron Zucker

Bluhm Joins Morton-Gregory

Appointment of Leslie E. (Bud) Bluhm as Milwaukee field engineer for the Nelson Stud Welding Div. of Morton-Gregory Corp. has been announced by Leonard C. Barr, vice-president and general sales manager of the Nelson Div.

Bluhm, whose office will be at Suite 207, 312 E. Wisconsin Ave., represented the Nelson organization in Washington, D. C., as field engineer from 1945 to 1947, and recently returned to the company after more than a year as yard welding engineer in the Boston Naval Shipyard.

A native of Milwaukee and an engineering graduate of Marquette University, he was with the research department of the Allis-Chalmers Mfg. Co., for four years prior to 1941, when he joined the Navy as a welding engineer at the Bureau of Ships.

He is a member of the AMERICAN WELDING SOCIETY.

Leslie E. Bluhm

NET MONTHLY ADVERTISING RATES
Black and White **Effective July 11, 1947**

Space	One Insertion	Three Insertions	Six Insertions	Twelve Insertions
*Full page	$185	$165	$150	$140
Two-thirds page	130	120	110	100
Half Page	105	95	85	80
Quarter Page	60	58	55	50
Eighth Page	40	35	30	28
*Inside Preferred	205	185	170	160

10% Extra for bleed full pages. Color $65 extra per color added
Agency Commission —15%
Cash Discount — 2%, 10 days

Time Counts—
Gas cut and Weld with
Shawinigan Carbide
SHAWINIGAN
SHAWINIGAN PRODUCTS CORPORATION
EMPIRE STATE BUILDING, NEW YORK 1 N.Y.

WELDING CONNECTORS
Saxe System Welded Connection Units
for welded assembly
Saxe Units place in position and securely hold together structural parts to be welded.
As used in many welded structures they *eliminate all hole punching* producing an economical, rigid, safe and quickly erected structural frame.
"Write for 58 pg. Manual containing full engineering design information for welded structures."
J. H. Williams & Company
Buffalo 7, New York
G. D. Peters Company
Montreal 2, Canada
Canadian Representative

TIP CLEANING DRILLS
Mounted in Knurled
BRASS *Handles*
LARGE STOCK
PROMPT DELIVERY
DISTRIBUTORS WANTED
NEW MEXICO STEEL CO.
Box 1546, Santa Fe, N. M.

NEW PRODUCTS

Victor Announces Four Outstanding New Fluxes

Victor Equipment Co., 844 Folsom St., San Francisco 7, announces the development of four new fluxes. They are:

Victor No. 3 Flux for brazing brass and bronze, steel, clean cast and malleable iron.

Victor No. 5 Flux for moderate heat brazing of cast and malleable iron. Does excellent job of "tinning" dirty castings.

Victor No. 7 Flux for high-heat brazing of cast and malleable iron where base metal gets exceptionally hot.

Victor No. 9 Flux for fast, effective welding of cast iron. Will not cake when container is subject to moderately high heat.

The manufacturer claims these new fluxes fulfill all the following requirements of an outstanding flux: they effectively clean both parent and filler metal, they cling to the heated rod when it is dipped into the flux, they do not blow off rod, they leave the finished braze clean, they contain no useless nor toxic ingredients, they effectively "tin" burned spots in cast iron brazing and they do not encourage cooling of cast iron welds.

These new Victor fluxes will be sold through all welding supply dealers. Write today for dealership information.

Kwikflux Granted Third Patent

Special Chemicals Corp. has recently been granted its third patent for its line of brazing and soldering fluxes marketed under the brand name, Kwikflux. This last patent covers Kwikflux #54, a superior fluxing agent with vastly improved wetting and penetration action, for all types of hard soldering, brazing and welding.

The manufacturer will send a free sample on request. Write to Special Chemicals Corp., 30 Irving Place, New York 3, N. Y., mentioning type of work for which it is to be used.

Welded Cylinder Trucks

Adams Mfg. & Supply Co., Los Angeles, announces complete improvement and change in their line of welding cylinder trucks. Trucks to carry any size welding cylinders in tandem or side by side, are included. In some cases design has been changed to provide better balancing. Trucks are available with Adams close fitting welded wide spoke steel wheels or with the finest ball bearing, rubber tired industrial wheels.

The complete line is illustrated in a new catalog just off the press. The Adams-steel wheel, sold separately, is also shown. Copies may be obtained from Adams Mfg. & Supply Co., 1522 N. Indiana St., Los Angeles 33, Calif.

Hardfacing Alloys

The Air Reduction Sales Co. has announced the immediate availability of a complete new line of hardfacing alloys bearing the famous Airco trademark.

Divided into three primary groups, ferrous alloys, cobalt base alloys and tungsten carbide, there are a total of fifteen Airco hardfacing alloys available. According to the manufacturer, this is the largest, most complete line of hardfacing alloys on the market today. Especially developed to combat abrasion, impact, heat and corrosion, the new Airco hardfacing alloys will increase the work-life of your equipment from two to twenty-five times.

In order to stimulate the introduction of this latest member of the Airco welding family, the manufacturer is making a special offer of a trial assortment of alloys. The assortment consists of the new Airco-lite hardfacing alloy especially recommended for equipment subjected to severe abrasion and medium impact such as pulverizer hammers and core crusher rolls (for oxyacetylene and electric arc application) and the new Airco self-hardening alloy for equipment subjected to severe impact and abrasion such as bucket teeth and sizing screens (electric arc).

This trial assortment is being made available at the special price of $2.95. According to Airco, the assortment contains a sufficient quantity to assure an adequate performance test. Also included in the trial offer package are instruction sheets for each of the two alloys plus a comprehensive descriptive booklet covering the entire hardfacing line.

To receive your trial assortment of Airco's new hardfacing line send your check for $2.95 to Air Reduction Sales Co., 60 E. 42nd St., New York 17, N. Y., or to the Airco Sales office nearest you.

Single-Phase Control for Resistance Welding

A single-phase-to-single-phase low-frequency electronic welding control that has a lower kva. demand and a higher power factor than the standard single-phase-to-single-phase control is available from Westinghouse Electric Corp. It makes possible welding of scaly or rusty steel with a minimum of spitting from the electrodes and also can be used for welding brass or aluminum.

This control is a frequency converter which, by means of electronic tubes, converts current at line frequency to current

Fig. 1 Westinghouse single-phase-to-single-phase electronic control for resistance welding

at lower frequency. The complete unit consists of three basic components: (1) a sequence panel which coordinates electrical functions of the control with the mechanical functions of the welder; (2) a frequency control circuit which transforms line frequency into a lower frequency; and (3) a weld timer which times duration of the welding current.

The control is designed for connection to a resistance welding machine having a specially constructed transformer with a center tapped primary. Operation of the control is such that current is passed in one direction through the primary for four half-cycles, stopped and then reversed for four half-cycles thus producing a low-frequency alternating current on the output side of the transformer. The electronic circuits accurately control the duration of each of these one-half cycles.

Further information about the single-phase control for resistance welding may be obtained from the Westinghouse Electric Corp., P. O. Box 868, Pittsburgh, Pa.

Resistance Welding Electrode Holder

Development of a new, leakproof, water-cooled resistance welding electrode holder is announced by P. R. Mallory & Co., Inc., Indianapolis, Ind. Production is now under way on the new line, which is being marketed under the name, Mallory "KO Holders."

Among the major improvements achieved in designing the improved leak-proof holders is the elimination of the problem of drops of water which cause rust or discoloration of the material being processed. This result is accomplished by the use of standard size O-Rings in place of ordinary packing.

Mallory is using copper alloy, brass or stainless steel for the complete assembly, including all internal parts of the "KO Holders." This insures full water flow for the life of the unit and keeps the tip ejector mechanism free from any rust or corrosion which might interfere with its easy, efficient action.

Before releasing this new product to industry, Mallory had it subjected to strin-

This FAST Welder –

is slow with your dollars

You gain a real production advantage when you accelerate metal joining operations while cutting fabrication costs. And Westinghouse automatic welders have just what it takes to give you this important advantage.

First, Westinghouse gives you a complete automatic welding machine in a single package. There's no costly waiting while welding heads are secured from one source, transformers and control from another, and positioning equipment from still another. Westinghouse machines are built and sold as a complete unit, ready for installation. There's just one source . . . one responsibility.

Then, truly big savings are gained when operation begins. By simple pushbutton operation you gain greater speed in joining part to part, plus a consistent high-weld quality that means fewer rejects. Lastly, the versatile Westinghouse Weldomatic head, *adaptable to five separate welding processes,* offers attractive savings in first cost and in change-over costs when a change in process becomes necessary.

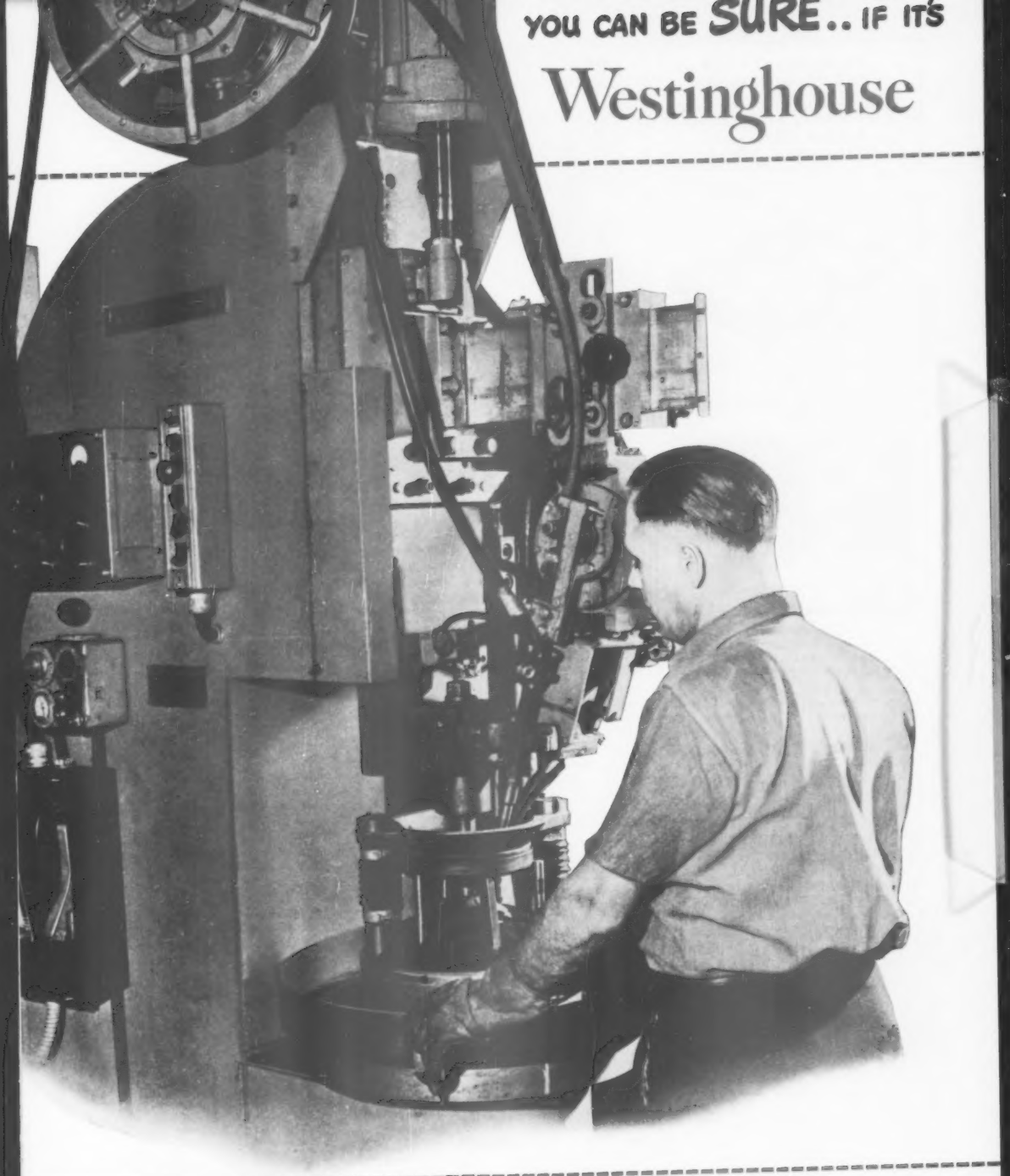
Westinghouse engineers are ready to assist you in applying this cost-saving equipment to your work. Full details on all types available are contained in booklet B-3928. Address: Westinghouse Electric Corporation, P. O. Box 868, Pittsburgh 30, Pennsylvania. J-21507

Westinghouse

EVERYTHING
FOR WELDING ANYTHING

YOU CAN BE **SURE**.. IF IT'S

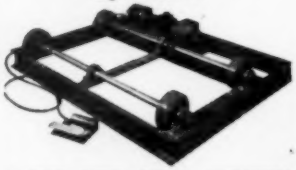
Westinghouse



TURNING TANKS IS OUR BUSINESS!

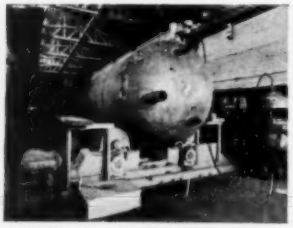
YOU'LL WELD 'EM AT LESS COST IF YOU USE REED *ENGINEERED* TURNING ROLLS

THE ONLY COMPLETE LINE OF MODERN TANK WELDING EQUIPMENT



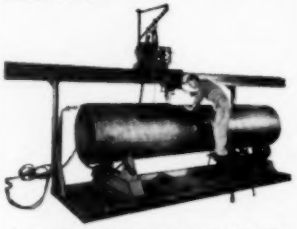
★ **THE NEW RD-20 TURNING ROLL**

Cap. 2,000 lbs.—handles up to 6 ft. × 12 ft. tanks. Priced at $650.00 F.O.B. Factory. Described in Bulletin No. 70.



★ **HEAVY DUTY TURNING ROLLS**

Built in 5 standard sizes, 3 ton, 6 ton, 12½ ton, 25 ton and 50 ton. Complete details shown in Bulletin No. 68.



★ **UNIT TYPE FOR AUTOMATIC WELDING**

Combines Turning Rolls & Track Support into one compact unit. Made in 5 standard sizes—Special units made to order.

★ **POWER DRIVEN PIPE ROLLS**

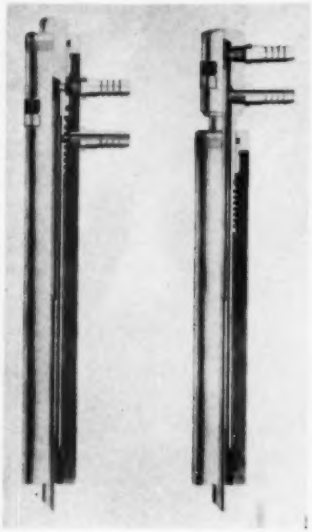
For accurate fit-up assembly & welding. Both standard & special units built to your requirements.

We Build a Complete Line of Tank Welding Equipment Including Bending Rolls, Assembly Presses, Horn Jigs, Track Support & Welding Gantries.

COMPLETE INFORMATION MAILED AT YOUR REQUEST

REED ENGINEERING CO.

CARTHAGE, MISSOURI U. S. A.

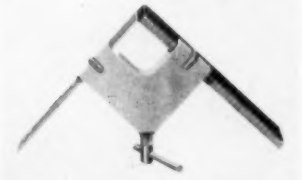


gent laboratory tests in which the ejector mechanism was operated more than 50,000 times under water pressures far greater than encountered in normal usage. The "KO Holders" met these rigid tests without difficulty.

Inquiries from Industrial users are invited. They should be directed to P. R. Mallory & Co., Inc., 3029 E. Washington St., Indianapolis 6, Ind.

Welder's Clamp

A new time-saving accessory for the welder has been brought out by the Thermacote Mfg. Co., 420 S. San Pedro St., Los Angeles 13, Calif. with branches in Newark, Chicago and Portland, under the name of "Korner-Klamp."



When two pieces of metal are to be welded together at right angles, they are inserted in the Korner-Klamp and the screw is tightened. They are thus secured at a correct 90° angle regardless of whether or not the two pieces are of the same or different thickness, maximum thickness being $\frac{5}{8}$ in.

These clamps have proved extremely useful in the construction of frames of all kinds, such as frames for agricultural implements, carrier frames, etc. Korner-Klamps are now being marketed through regular jobber and dealer channels in the welding trades.

Templates

Here is a remarkable new invention that reduces layout work involving curves to a mere fraction of the usual time! The unique Flexible Template duplicates curves full size in a matter of seconds, often saving hours of curve plotting, tedious drawing and template making. Can be set and locked to any desired shape, contour, curve or radius and transferred anywhere for construction or checking purposes. Springs back to original position when unlocked, ready for reuse. Used to copy curves from blueprints, to take off construction lines, and in many other ways. Eliminates trial-and-error fitting wherever curved materials must be fabricated or duplicated.

Rapidly becoming an indispensable tool for construction and repair workers in wood, metal, glass, plastics, paperboard, wiring and piping. Accurate, rugged spring steel and aluminum construction. Available in lengths of 1-ft. intervals. Shortest length 2 ft. Price only $3.75 per foot, f.o.b. Camden, N. J.

For further information write C. H. Clark and W. E. Poggenburg, 4900 Wynnefield Ave., Philadelphia, Pa.

First-Aid Eye Kit

Following a survey made to first-aid dispensaries in plants throughout the country, two registered pharmacists associated with Ohio First Aid & Pharmacal Co., 1285 W. 6th St., Cleveland, Ohio, developed a first-aid kit for eye safety and health.

Opticlean First-Aid Eye Kit has been designed to eliminate many of the dangers of impromptu first-aid treatments for eye injuries. Not intended to replace professional services or for promiscous use by untrained personnel, Opticlean kits put the best possible first-aid equipment in the hands of the first-aider who is instructed what first aid he can give in eye injury cases as well as what he should not do.

The kit contains 15 eye health items which include eye patch, eye pads, adhesive strips, eye droppers, eye cup, cotton balls, cotton swabs, eye drops, castor oil, boric acid solution, boric acid ointment

and the new Magna-Clean Eye Particle Remover. This last is a nonbreakable plastic magnifier which locates particles and then mechanically removes the foreign object with a specially smoothened wire loop. The magnet used is the G. E. Cunife Magnet, the finest permanent mechanical magnet obtainable.

All the items are housed in a sturdy plastic box, transparent and air-tight. All the items are clearly visible. The kit measures $8^1/_4$ x $4^1/_4$ x $1^1/_4$ in.

The kits are recommended as auxiliary equipment for regular first-aid kits. Refill materials are readily available. All kits are prepared and assembled under the supervision of registered pharmacists. The complete Opticlean Eye Kit is priced at only $3.95, Cleveland, Ohio.

Inert-Gas-Shielded Spot-Welding Torch

A new portable, inert-gas-shielded spot-welding torch has been developed by The Linde Air Products Co., Unit of Union Carbide and Carbon Corp. With this torch, called the Heliarc HW-8, you can make spot welds from only one side of the work without the necessity of backing the weld location. The sketch, Fig. 1, shows the typical use of torch spot welds in the construction of a corrugated sandwich.

Mild steel, low alloy and stainless steel, 0.030 to 0.064 in. thick can all be welded using currents from 155 to 250 amp. Not only can two sheets of these metals be joined in one to two sec. per spot, but also a sheet of metal can be joined to underlying material of any thickness. This makes it possible to spot weld corrosion-resistant sheets to mild steel to provide cladding.

The torch is especially useful where the structure is large or of complicated shape because welding is done from one side and no forging pressure is required. Argon gas shields the electrode and weld area to prevent oxidation. Welding duration and argon flow are accurately controlled by a separate timer unit. This torch uses alternating or direct current with high frequency starting and stabilization of the arc.

The Heliarc HW-8 torch is lightweight, pistol-shaped and trigger operated. No special training or technique is required. The torch is easy to use. Merely press the "muzzle" of the "gun" against the work and pull the trigger.

Only one hose assembly connects the torch to the accessory equipment which can be thus placed out of the way to leave the entire work area free. The standard hose assembly, 25 ft. long, is about an inch in diameter and contains conductors for power cable, cooling water, shielding gas and trigger control. Electrode adjustment is easily made by push button release located on the torch. All of these features make the spot welding torch an ideal production line tool that is easy and natural to use and as light and portable as an oxy-acetylene blowpipe.

Start-Stop Control for D.-C. Electric Driven Welders

DV Automatic Start-Stop Control for electric driven d.-c. welders enables operator to start welder instantly by merely "striking an arc," without having to leave work or push buttons. Control shuts off welder after 2 min. (adjustable) of no-welding. Running time of welder is frequently cut in half, thus effecting changes in equipment wear and maintenance costs. In most instances power savings exceed full cost of DV Control in first year of use.

Overloads are reduced, power factor is improved, and both the kw. demand and the kw.-hr. energy consumption are lowered. Newest model of DV Control incorporates several improvements over previous models, many of which have been in service for over five years. All-metal clutch design and steel frame provide greater uniformity and longer life under adverse conditions of use. New descriptive bulletin contains full specifications. Manufactured by DV Welding Controls, Oakland 11, Calif.

New Tempil Products

Tempil° Corp. of 132 W. 22nd St., New York 11, N. Y., announces the development of additional temperature ratings of Tempilstiks° (crayons), Tempilaq° (liquid) and Tempil° Pellets to provide industry with a fuller range of these temperature-indicating products.

All three products are now, for the first time, available in $12^1/_2$-degree intervals from 113 to 400° F.

From 400 to 1600° F. Tempilstiks° and Tempilaq° are available in 50-degree increments while Tempil° Pellets can be had up to 1700° F.

Low Cost Automatic Fire Protection

Stop-Fire, Inc., well-known pacemakers in design of modern fire protection equipment, announce Underwriters' Laboratories listing of their automatic sprinkler "portable system" fire extinguisher.

This economical unit, constructed of heavy brass, silver welded, needs no piping or other expensive installation. Simply hang it up, and it is ready to operate, utilizing the new miracle fire-extinguisher fluid known as C.B.M., or Chlorobromomethane.

Flame does not have to touch this unit. When fire occurs, heat waves cause an approved sprinkler head, (like those on the best automatic water systems), to discharge under pressure a wide, fast-moving spray of combined carbon dioxide and atomized Chlorobromomethane. This quickly blankets and snuffs the fire, with absolutely no residue, stain or damage.

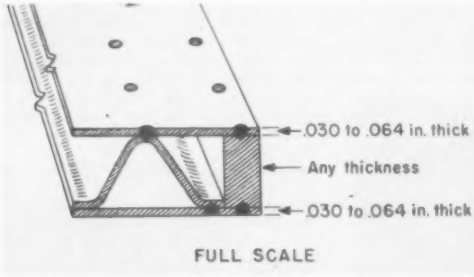


Fig. 1 A corrugated sandwich can be easily made by torch spot welding

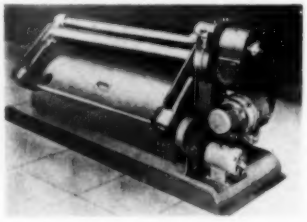
Fig. 2 The Heliarc HW-8 spot-welding torch

Equally efficient on oil, grease, flammable liquid, lacquer, paint, solvent, or electrical fires. It is nonfreezing, and has minimum specification capacity of 700 cu. ft.

Stop-Fire, Inc., 125 Ashland Place, Brooklyn 1, N. Y.

Bending Roll

Illustrated here is the new Series 600 plate bending rolls recently placed on the market by Reed Engineering Co. of Carthage, Mo. This machine is the latest addition to their line of heavy duty bending rolls which feature all-steel construction. The machine is equipped with three 6 in. diameter forged steel rolls and is driven through a totally enclosed worm gear drive. All bearings throughout the machine are made of solid bronze and are precision bored for the main roll journals.



Main frame and housings are built with welded construction, and housings are connected with antitorque type connectors to prevent twisting of frames during heavy rolling operations. This line of machines is built with an automatic drop end which automatically raises the top roll when the drop end is lowered for removal of fully rolled circles. Dual capacity ratings are given for all machines showing ratings for mild steel and also stainless steel. Standard equipment includes 5 H.P. squirrel cage motor with reversing control, three roll drive to main rolls and manual roll adjustment to two lower rolls. Power adjustment to rear forming roll, cone rolling attachment, magnetic brake motors and air operated drop end are available as optional equipment.

Dwarf Control Combination

The Weltronic Dwarf Control Combination, Model 106-53BA1, has been developed to satisfy the demand for an extremely compact, simple, inexpensive control. The N.E.M.A. 1A timer plus the high speed magnetic contactor makes this an ideal combination for small welders.

Standard models are for mounting to right hand side of welder. Control panel is placed so that controls face the operator. This compact control is enclosed in an attractive cabinet measuring only 17 in. high, 14⅜ in. wide and 8 in. deep. The control is a package unit, completely wired and ready to install.

A high-speed magnetic contactor is installed in a shock mounting. It is easily accessible for inspection. Never requires cleaning, dressing, or filing. Available in 100 or 150 amp. size.

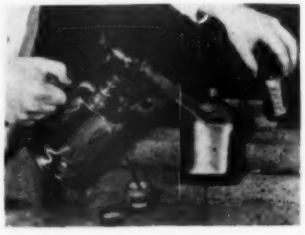
The timer (53BA1) employed is a single-stage weld timer. The weld time has a continuous adjustment from 3 to 120 cycles. Weld-no weld switch may be provided on the panel. Timer power supply operates from 115, 230, or 460 v. a.-c. source. Units for other voltages or 25 cycles operation may be supplied.

Complete details may be obtained by writing Weltronic Co., 19518 W. Eight Mile Rd., Detroit 19, Mich.

Silver Alloy Available for Home and Shop Use

A new high silver alloy and a handy pocket container have been specially developed for shop and home use. Eutectic Welding Alloys Corp., 40 Worth St., New York 13, N. Y., announces the availability of its new Eutec-Silver-Weld*

* Patent pending.



Pocket Economizer for the easy, low-heat joining of all metals, except aluminum.

This handy Economizer contains a coil of the new high silver alloy which feeds through a small hole in the top of the unit. A separate compartment in the bottom contains a jar of high performance Eutector Flux, that is scientifically developed for use with this alloy to insure lowest heat of application.

The Eutec-Silver-Weld* alloy has been specially developed for joining all metals and it is especially recommended for steel, copper, brass, bronze, stainless steel and malleable iron. It applies readily with all torches . . . oxyacetylene, gas, Prestolite and large gasoline torches.

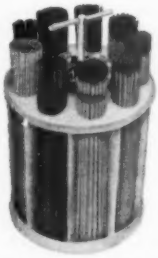
Eutec-Silver-Weld* pocket economizer will have a multitude of applications in shops for repairing household utensils, electrical connections, pipe and tube fittings, jewelry fabrication and a wide range of other metal-joining problems.

For additional information, write to Eutectic Welding Alloys Corp., 40 Worth St., New York 13, N. Y.

Rod-Hod Electrode Carrier

Marquette Manufacturing Co., Inc. of Minneapolis, Minn. recently announced their new Rod-Hod Electrode Carrier.

The Marquette Rod-Hod gives you a generous supply of over 30 lb. of famous Marquette electrodes. There are 16 sizes and types of rod to cover a wide range of welding. Contains the right rod for every welding job . . . No. 130 Red-Rod, No. 140 Production-Rod, No. 40 Blu-Rod, No. 85 Hy-Test-Rod, No. 100 Hard-Rod, No. 550 Hard-Rod, No. 650 Tool-Rod and No. 44 Nicol-Rod.



New Marquette Rod-Hod electrode carrier

The Marquette Rod-Hod saves time and protects electrodes. Each rod is instantly identified, no lost time. Designed especially for garages, weld shops, implement dealers, maintenance and repair shops. Saves wear and tear on pockets, saves time lost running back and forth hunting for welding rods. It is what welders have needed for years.

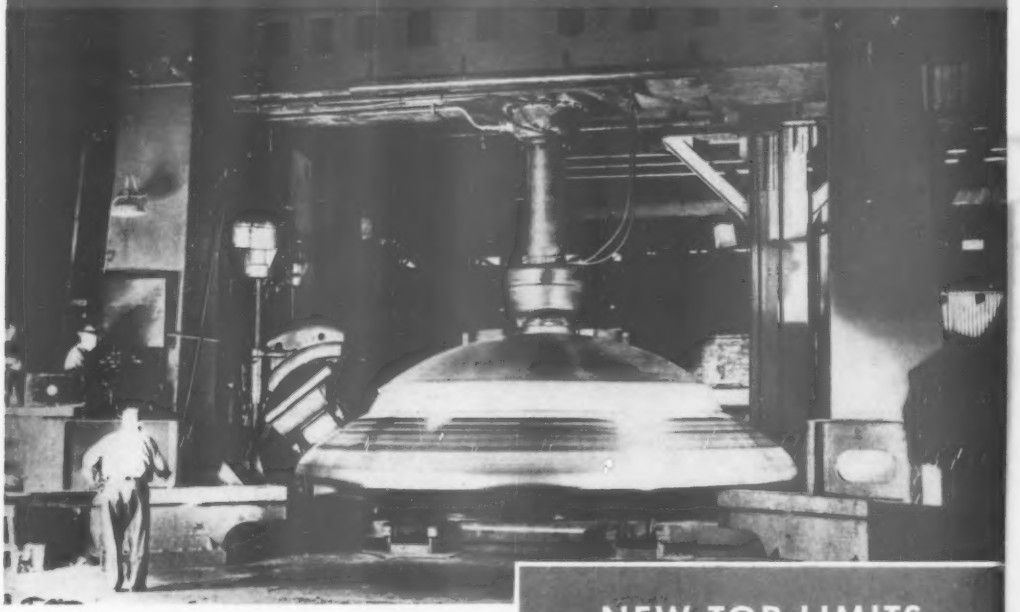
Marquette offers the complete Rod-Hod for far less than what you would pay for these quality electrodes at regular prices. Refill with 5 and 10 lb. Marquette Rod-Pak. Sold exclusively thru the nation's leading distributors.

A descriptive circular describing this new Rod-Hod Carrier available on request.

Lukens now spins the

WORLD'S LARGEST HEADS

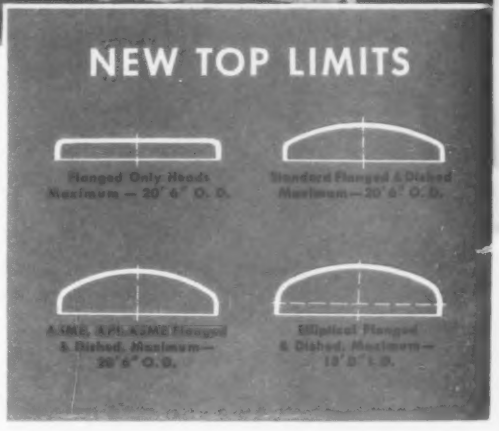
. . . up to 20'6" O.D.



It's another "World's Largest" for Lukens—this new machine, capable of spinning heads up to 20′ 6″ in outside diameter. Now it is seldom necessary to resort to sectional flanging of heads with accompanying construction and X-raying problems.

64 years of head-forming experience at Lukens went into the design of this new machine. That same know-how guides the production of Lukens Heads in the widest range of sizes, gages, styles and materials obtainable, including Clad Steels and nonferrous metals from 4″ to 20′ 6″ in diameter, or from 3/16″ to 6½″ thick.

In addition to the 3989 standard Lukens Heads listed in Catalog No. 1, obtainable promptly from dies available, Lukens has many sizes of Standard and ASME Flanged and Dished Heads in stock listed in Bulletin 433. For copies, write Lukens Steel Company, 407 Lukens Building, Coatesville, Pennsylvania.



LUKENS HEADS

★

"Head Work", a 16mm motion picture in sound and color, on spinning and pressing of Lukens Heads is available without charge. Running time: 27 minutes. Write for a booking date.

FOUR INCHES TO OVER TWENTY FEET IN DIAMETER

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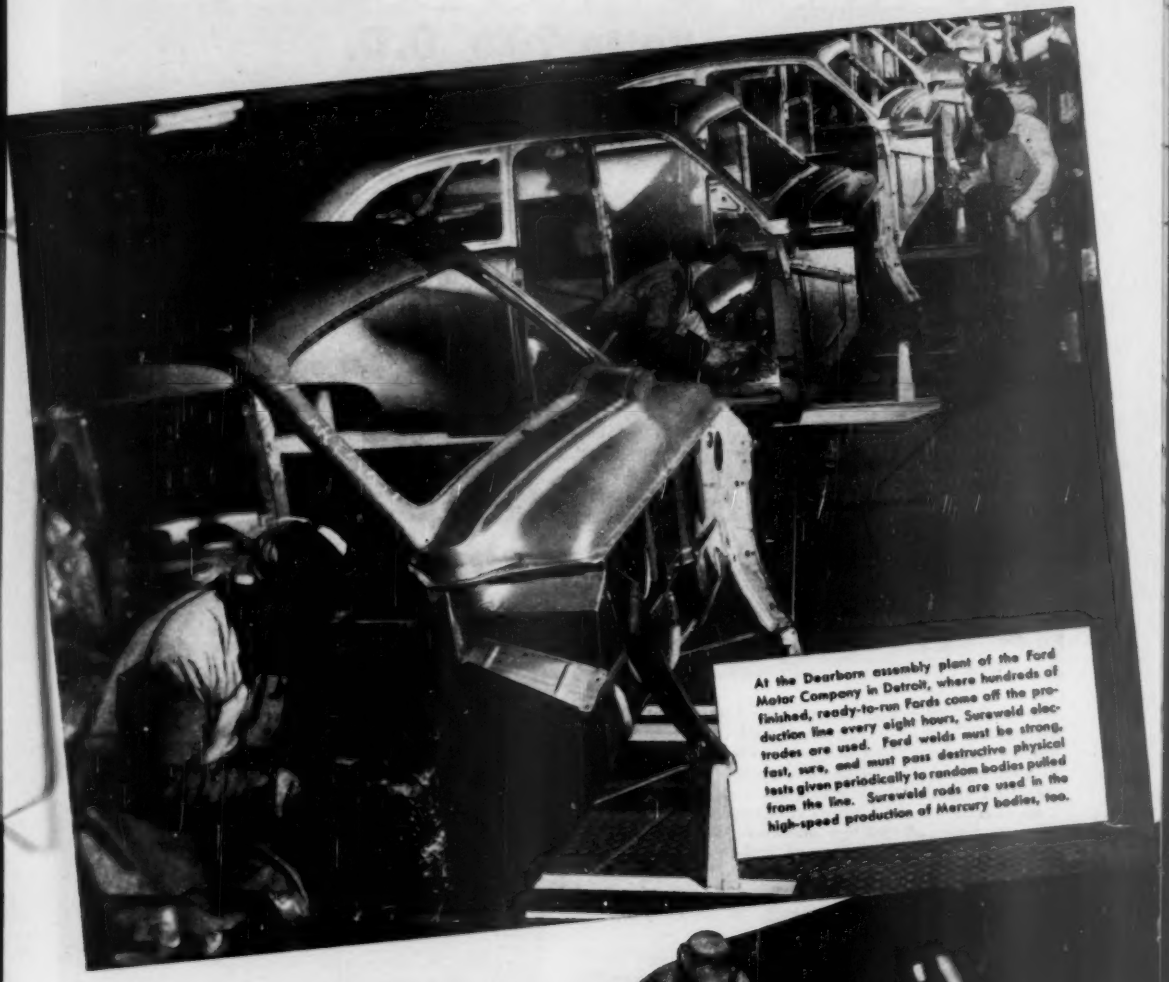

At the Dearborn assembly plant of the Ford Motor Company in Detroit, where hundreds of finished, ready-to-run Fords come off the production line every eight hours, Surewold electrodes are used. Ford welds must be strong, fast, sure, and must pass destructive physical tests given periodically to random bodies pulled from the line. Surewold rods are used in the high-speed production of Mercury bodies, too.

For 10 years, Norris Iron and Wire Works Inc. has used NCG products exclusively to make production step along in its Bridgeport, Pa. plant. General steel fabricators specializing in buildings, coal conveyor systems, galvanized towers and heavy structural work, Norris relies on Surewold electrodes and NCG gases and apparatus, using a money and time saving NCG manifold system for oxygen and acetylene.

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WHERE there's large-scale, high-speed production, you're more than likely to find performance-proved Sureweld Electrodes—because Sureweld Electrodes are *dependable*—for speed, for weld-strength, for uniform welding characteristics. Production lines keep moving—with less clean-up and greater ease of operation for *every* welder. . . . Join the *thousands* of satisfied Sureweld users! There's a Sureweld Electrode for *every welding job.*

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The new Sureweld AC-DC 18-8 Stainless Steel Electrode is used to join manganese castings with mild steel parts in the fabrication of draglines, pull shovels and clamshell buckets at Pettibone Mulliken Corporation, Chicago—America's largest manufacturers of this kind of equipment. PM's high-speed 16-booth mechanized welding production line, where all work is multiple-pass welding, necessitates easy slag removal and strong, neat welds.

abstracts of CURRENT WELDING PATENTS

prepared by V. L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington 10, D. C.

2,457,193—Electrode Holder—Arthur R. Wynn, Long Beach, Calif.

Wynn's patented holder includes a solenoid having a tip at one end thereof adapted to receive an electrode. An axially movable core is positioned within the solenoid and aids in positioning an electrode in the holder.

2,457,215—Gas Welding Rod—John Trimble Eash, Westfield, N. J., assignor to The International Nickel Co., Inc., New York, N. Y., a corporation of Delaware.

This patent relates to a method of producing welding rods which have a surface free from releasable silica-containing particles. The rod is made from a nickel-chromium cast iron which has a calcium-containing agent added thereto sufficient to introduce between about 0.05% to about 1.0% calcium into the material.

2,457,372—Alternating Current Vertical Welder—Edward A. Hobart and Russell T. Flora, Troy, Ohio, assignors to The Hobart Bros. Co., Troy, Ohio, a corporation of Ohio.

The welding transformer covered in this patent includes a pair of relatively movable transformer coils having adjusting means for controlling the positions thereof. A uniformly graduated indicator dial is provided to show the output of the transformer and means also are provided for actuating the dial to variably spaced positions during the relative movement between the coils, which means are dependent upon the coil moving means.

2,457,459—Press for the Covering of Electrode Rods—Karl Gloor, Zurich, Switzerland.

A special press for coating electrode rods is disclosed in this patent.

2,457,606—Welding Gun—Charles Senn, Detroit, Mich.

The welding gun of this patent includes a head having an electrode secured to and projecting therefrom with a shank projecting upwardly from the electrode. A cylinder is secured to the shank and piston means are received therein in association with the shank whereby a pressure fluid can be supplied to the cylinder for forcing the electrode against the work whereas the pressure fluid entering another portion of the gun will retract the cylinder and shank and move the electrode away from the work.

2,457,675—Electrode Control—Robert L. Hinds, Toledo, Ohio.

Hinds' patent covers an electrode directing holder comprising a tubular insulation portion that has a partition therein with an open ended electrode mounting conductor sleeve being positioned on each side of the partition. One end of each of such sleeves extends beyond the insulating partition in the holder and they have their ends tapered and diverging with relation to each other to form a V open in extent away from the tubular insulation partition. An electrode is positioned in each sleeve and protrudes into the V formed between the sleeve ends.

2,457,704—Material Supporting and Cooling Apparatus for Welding Machines—Donald H. Mitchell, Cranford, and Earl C. Moss, Westfield, N. J., assignors to Western Electric Co., Inc., New York, N. Y., a corporation of New York.

The patented apparatus is particularly adapted for use with a device which previously has been welded and has residual stresses therein. The apparatus includes means for supporting a metallic element in association with a workpiece and means for directing a coolant on the opposite surface of the workpiece adjacent the metallic element to prevent spreading of heat during the welding of the metallic element to the workpiece.

2,458,340—Method of Electrically Welding Composite Metal Reel Heads.—Arthur A. Bureau, Chicago, Ill., assignor to Western Electric Co., Inc., New York, N. Y., a corporation of New York.

This welding method relates to the formation of a reel head and comprises the steps of assembling inner and outer annular metal members in abutting relation to an intermediate annular metal member, after which special arcuate electrodes are brought into association with the metal members to weld alternately successive portions of the inner and outer members to the intermediate member.

2,458,658—Electric Arc Welding—Joseph M. Tyrner, New York, N. Y., assignor to Air Reduction Co., Inc., New York, N. Y., a corporation of New York.

In this patent the welding apparatus includes a generator for supplying current to the welding circuit and having a field winding which has a separate excitation current supplied thereto. Control means for the excitation current supplying means are provided and are connected to the welding circuit for varying the excitation current inversely to the welding current to maintain the welding current substantially constant throughout the range of welding voltage.

2,458,688—Welding Cupro-Nickel Alloys—Charles H. Davis, Cheshire, Conn., Assignor to The American Brass Co., Waterbury, Conn., a corporation of Connecticut.

The welding method of this patent relates to welding parts made of a copper-nickel base alloy and the patent contemplates addition to each of the alloys to be welded together of from 0.02 to 0.1% magnesium. The parts are heated to welding temperature in the absence of any flux and in the presence of a filler made from a copper-nickel base alloy containing magnesium to the same extent as the alloys to be welded together.

2,458,723—Electrode Holder—Gustaf F. Nilsson, Minneapolis, Minn.

Nilsson's patented holder includes a plunger slidable along an elongated case with the plunger having a V-shaped groove in one end of the same opening laterally of the plunger for the reception of a welding electrode. A jaw is associated with the electrode and a spring urges the jaw toward the groove in the plunger for retaining an electrode therein. The jaw urges the electrode toward the vertex of the groove and the jaw is moved inwardly toward the apex of the groove upon longitudinal movement of the plunger in the case receiving same.

2,458,758—Apparatus for Resistance Welding—Edward J. Zulinski and Robert Barley, Detroit, Mich., assignors to Progressive Welder Co., Detroit, Mich., a corporation of Michigan.

The resistance welding apparatus in this instance includes a first control means for actuating a control mechanism and applying a substantially constant initial pressure between the electrode and the work. A first and a second independently operable time delay means are provided with the first time delay means being operative to initiate at the expiration of a predetermined time an increase in the initial pressure between the work and the electrode. The second time delay means provides an impulse of welding current between the work and the electrode.

2,458,928—Welding Fixture—Percy E. Brooks, Woodridge, N. J., assignor to Western Electric Co., Inc., New York, N. Y., a corporation of New York.

The welding fixture relates to a welding machine having relatively movable first and second electrodes with work engaging surfaces initially lying in parallel planes.

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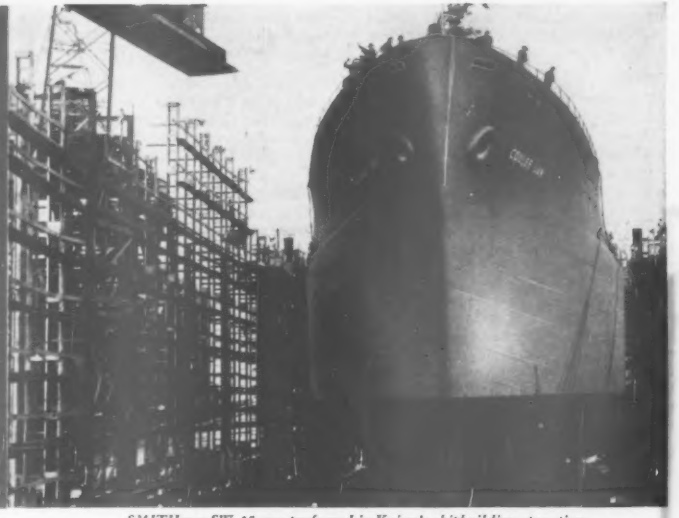

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The fixture comprises a wear-resisting element surrounding the first electrode and having a guide surface so that an end portion of the electrode may be positioned to protrude from the guide surface. An abrasive tool is provided for movement with relation to the guide surface of the wear-resisting element whereby an end portion of the first electrode may be removed to produce a true work engaging surface for the electrode, which surface would lie in the plane of the guide surface of the wear-resisting element.

2,459,047—Method and Apparatus for Electric Arc Welding—Paul B. Scharf, Bradford, Pa., assignor to Dresser Industries, Inc., a corporation of Pennsylvania.

This novel welding method relates to welding together the abutting end surfaces of electrically conductive cylindrical sections. The method comprises striking and maintaining an electric arc between an arcing element and the end portions of the sections while effecting rapid relative rotation between the sections and elements. This action is maintained until a narrow band of material adjacent the end surfaces of the metal sections is heated throughout its entire circumferential extent after which the end surfaces are pressed together to effect a weld therebetween.

2,459,153—John H. England, Wellesley Hills, Mass.; 2,459,154—Assignor to Raytheon Mfg. Co., Newton, Mass., a corporation of Delaware.

These patents upon a welding system relate, in general, to one wherein a condenser is provided and coupled to a welding load circuit so that the condenser can be discharged through the welding load circuit to provide a unidirectional pulse of current during which the condenser is charged in an inverse direction. A shunt circuit is provided across the condenser and means, responsive to the termination of the pulse of current, are provided for closing the shunt circuit to reverse the polarity of the inverse charge on the condenser thereby partially recharging the same with the original polarity.

2,459,242—Blanketed Electric Welding with a Fusible Trough to Support the Comminuted Mineral Composition Above the Bottom of the Welding Zone—Frank Rothe, Niagara Falls, N. Y., assignor to The Linde Air Products Co., a corporation of Ohio.

This patent relates to electric welding of work composed of metal parts with an electrode of fusible metal under a blanket of comminuted mineral composition. A welding groove is provided between the parts to be welded which groove is separated by a thin partition of fusible metal into upper and lower portions and comminuted mineral composition is supplied to the upper portion only of the welding groove. The electrode is moved longitudinally with respect to the groove to progressively melt the electrode and partition under the mineral composition as the welding operation progresses so as to complete the weld in both portions of the groove in a single pass.

2,459,577—Welding Apparatus—Clayton P. Nielsen, Chicago, Ill., assignor to Mid-States Equipment Corp., a corporation of Illinois.

Nielsen's patent relates to a control system for a welding apparatus wherein a transformer means is provided with first and second secondaries for supplying energy to the welding arc gap. The system includes a relay having a switch associated therewith and a pair of energizing coils. The relay is adapted to connect both energization coils thereof to one transformer secondary coil when the weld arc is extinguished for applying a relatively low voltage to the welding arc gap. In other positions, the relay has only one operative coil therefor connected in the circuit which includes both secondaries of the transformer and applies relatively large current to the welding gap when the welding arc gap is established.

2,459,625—Welding Together Metal Strip Ends—Warren F. Copp, St. Clairsville, Ohio, assignor to Wheeling Steel Corp., Wheeling, W. Va.

This welding method comprises disposing metal strip ends in nonparallel but generally coplanar relation with the metal of one strip adjacent the end thereof being transversely straight and the metal of the other strip adjacent the end thereof being transversely buckled. A flash line weld is used to progressively join the strip ends and before hardening of the weld the strip ends are moved and the buckle in the second dimension strip is eliminated to produce a weld which is substantially uniform along the weld joint.

LIST OF NEW MEMBERS

January 1 to January 31, 1949

ANTHONY WAYNE

Foltz, Glen C. (B)
Gaby, Carl L. (C)
Houk, Robert C. (C)

BOSTON

Taverna, Domenic P. (B)

CHATTANOOGA

Kaderly, J. M. (B)

CHICAGO

Savage, John C. (C)
Youngberg, Richard W. (C)

CLEVELAND

Ball, C. I. (B)
Brown, A. A. (B)
Cawrse, Llewellyn S. (C)
Fulton, E. G. (B)
Grinstead, Laurence (C)
Herholtz, J. E. (B)
Lafferty, Thomas R. (C)
Manning, D. C. (B)
Matlow, George (B)
Mothorpe, Bruce (C)
Saiter, Paul S. (C)

COLUMBUS

Cooper, James (B)
Fletch, Eddie J. (C)
Hirsch, E. G. (B)
Holsclaw, John W. (C)
Seymour, Homer A. (C)

DAYTON

Beard, Max I. (B)
Flora, Russell T. (C)
Grimes, W. F. (C)
Schneider, Siebert (C)

DETROIT

Baker, Laurence (C)
Benson, G. B. (C)
Cobb, W. H. (C)
Dale, Stanley A. (C)
Erickson, Donald G. (D)
Formolo, Ernest C. (C)
Hart, Charles H. (B)
Loup, Ronald L. (C)
Mase, Joseph A. (C)
Neail, Edward A. (D)
Panik, Joseph J. (C)
Rainey, James E. (B)
Revere, Vernon E. (D)
Sendoykas, Jack John (C)
Solin, John G. (B)
Trella, George A. (B)
Underberg, Anthony (B)

KANSAS CITY

Blake, P. D. (C)

LEHIGH VALLEY

Baucher, Elwood (C)
Reed, George (B)
Smith, H. C., Jr. (C)

LONG BEACH

Maitlen & Benson, Inc. (B)
Rowland, Vernon (B)

LOS ANGELES

Dotson, Donald J. (C)
Fleek, William (C)
Nash, William F., Jr. (B)
Stewart, Robert C. (C)
Stewart, Russell E. (C)
Thomas, J. D. (C)

LOUISVILLE

Bowser, L. P. (B)

MAHONING VALLEY

Braden, Charles W. (C)
Lefebvre, Henri (B)

MARYLAND

Pattison, Paul G. (B)
Tarr, Allan L. (B)

MICHIANA

Baker, Dean A. (C)

MILWAUKEE

Crosby, Laurence G. (C)

Fisher, Robert J. (B)
Klumpp, Elmer E. (B)

NEW JERSEY

Kozsik, John F. (C)
Powers, W. Robert (C)
Sumpman, Glenn (C)
Wery, Albert G. (C)

NEW YORK

Gardner, Annesta R. (C)
Haller, Elliot A. (B)
Hill, Robert M. (B)
Meredith, Lyle H. (B)
Croyle, Harry A. (C)

NIAGARA FRONTIER

Arensdorf, Edman P. (C)
Cardis, David E. (B)
Schmits, Gerard J. (C)
Seibel, William E. (C)

NORTHERN NEW YORK

Hills, Wm. B. (C)
Utting, Ross P. (C)

NORTHWEST

Jensen, Asger M. (B)

NORTHWESTERN PA.

Andersen, C. S. (B)
Butcher, Clarence S. (C)

PHILADELPHIA

Dooley, Charles Lewis (C)

PITTSBURGH

McCullough, Wm. B. (B)

PORTLAND

Wilson, James T. (B)

PUGET SOUND

Jackson, Robert A. (C)

ROCHESTER

Chippero, Alfred P. (C)
Johnson, Leslie (B)
Hutchison, Robert W. (C)

ST. LOUIS

Joslin, S. R. (C)
McGinnis, R. E. (C)
Thurston, Raymond D., Jr. (D)
Weigel, John Henry (B)

SAN FRANCISCO

Barbee, Robert J. (B)

SOUTH TEXAS

Schmuck, Howard K., Jr. (C)
Starke, W. R. (B)
Toops, Harry L. (C)

TOLEDO

Chandler, George L. (C)
Kleinsmith, Earl W. (C)

TRI-STATE

Wiltjer, Albert J. (C)

WESTERN MASS.

Kappler, Theodore William (C)

WORCESTER

Schultz, Albert J. (B)
Swan, Julian C. (C)
Wenzel, Roger W. (B)

NOT IN SECTIONS

Aixner, Ludvik (B)
Carlson, Edwin (D)
Chase, Roy B. (C)
Child, Rawson D. (D)
Christensen, Lynn J. (D)
Christofferson, Darwin (B)
Frazier, Arnold T. (D)
Gastpar, Jacques (B)
Hardman, Joseph H. (D)
Johns, Roland (D)
Johnson, Earl A. (D)
Larsen, H. Dean (D)
McGregor, Charles Robert (D)
McGregor, Donald (D)
McGregor, Wells P. (D)
Olsen, Ariel Lamar (D)
Sonderegger, Clayton (D)
Telford, Robert (D)
Weiler, Dipl. Ing. Julius (C)
Western, Grant L. (D)

SECTION ACTIVITIES

Prepared by C. M. O'Leary

To avoid possibility of inaccurate reporting in the write-up of Section Activities in The Welding Journal, no information will be included unless headquarters receives a definite write-up or a report indicating exactly what transpired at a specific meeting. Advance notice of such a meeting cannot be accepted as having actually happened unless accompanied by a signed statement or a report to that effect.

Anthony Wayne

Friday, January 28th, was the day on which the Anthony Wayne Section held its monthly dinner meeting in the Chamber of Commerce Dining Room, Fort Wayne, Ind. Vernon Carr, Magician presented a program of magic tricks which was enjoyed by all.

Frank McGuire of The Linde Air Products Co., presented an illustrated talk on "Heliarc Welding and Its Applications." New and interesting facts were given.

Birmingham

James F. Lincoln, President of The Lincoln Electric Co., was the coffee speaker at the February 3rd meeting held in Hooper's Cafe. Mr. Lincoln spoke on the comparison of code requirements for welded construction versus other types of construction.

The technical session was in the form of a round-table discussion of welding problems. The panel of experts included L. C. Stiles of the Chicago Bridge & Iron Co. (Moderator), W. B. Browning of The Linde Air Products Co., Gerald E. Schauerte of the Metal and Thermit Corp., J. R. McFarland of the Air Reduction Sales Co., George Yates of The Stoody Co. and John E. Durstine of The Lincoln Electric Co.

Bridgeport

Three speakers were scheduled at the January 20th dinner meeting held at the Candelite Restaurant, as follows: L. F. Bock of the General Electric Co., spoke on "The fundamental Controls of a Resistance Welder"; R. A. Lalli of the R. A. Lalli Co., spoke on "Tricks with a Torch," and J. R. Mitchell, Chairman of the Bridgeport Section, presented a "Review of Welding with Respect to Heavy Industry." This meeting held the interest of all present exceptionally well. It combined shop work and engineering talent effectively.

Chicago

A large attendance was noted at the January 21st meeting at which more than 130 members and guests were present. "Heating, Forming and Bending with the Oxyacetylene Process," was the subject of the technical session. The speaker, William A. Thiel, of the American Bridge Co., Gary, Ind., gave a clear presentation and illustrated his talk with chalk diagrams on a blackboard.

Thirty minutes of discussion followed the talk, with about 20 members of the audience asking questions. General interest in the new methods was indicated after adjournment also.

"Heavy Duty Towtrucks" was the title of one of the premeeting movies. The towtruck was shown lifting an 8-ton dump truck from a highway underpass to the level of the upper road. Built by Hudson Machine Works, Evanston, Ill., the truck was a GMC type modified and strengthened by welded construction. "Let's See Chicago" was the title of the other film.

About thirty members had dinner at Burke's Grille and Restaurant before the meeting.

The Chicago Section was represented at the Chicago Area Career Conference at the Illinois Institute of Technology on December 29th, by L. S. McPhee and T. B. Jefferson. Les McPhee was chairman and Ted Jefferson a speaker at the counseling section on welding. The purpose of the session was to acquaint the high-school seniors of Chicago with the requirements and opportunities of welding as a career. The discussion covered all types of welding in every phase of occupational activity from craftsman to engineer

Cincinnati

The Cincinnati Section had a very nice turnout for its first meeting in 1949 held on Tuesday, January 25th, at Engineering Society Headquarters. A short talk by

George Jacoby, Membership Chairman, preceded the regular meeting. After the meeting a "Dutch Lunch" was served for all members and guests.

Fred A. Kaufman, Metallurgical Engineer for the McKay Co., of York, Pa., spoke on manual metallic arc welding of mild steel, stainless steel and special alloys. His talk was illustrated with 16-mm. slides.

Cleveland

A magical evening was enjoyed by members of the Cleveland Section at their regular meeting on February 9th held at The Cleveland Engineering Society.

The magic came from both the General Electric Co.'s "House of Magic" and the fact that it was guest night and members were invited to "bring the ladies."

William A. Gluesing, who is in charge of the "House of Magic," is an electrical engineer, but has been interested in magic all of his life and has been in charge of the "House of Magic" science show since it made its debut before the Chicago Century of Progress World's Fair in 1933.

The show lasted a full hour and was followed by refreshments served buffet style for all members and guests.

Colorado

Ray L. Townsend, Manager, Tweco Products Co., and mid-Southern District Vice-President, A.W.S, was the speaker at the January 18th meeting held at the Silver Wing Inn, Denver. Mr. Townsend's subject was "Robbery in the Welding Shop." A film "History of Welding" was also shown.

Columbus

The January meeting of the Columbus, Ohio Section was held jointly with the A.S.M. at the Fort Haynes Hotel on Tuesday, January 11th.

The coffee talker, Joseph A. Park, Dean of Men of The Ohio State University, gave a very enjoyable talk on Scottish humor, liberally interspersed with anecdotes and Scottish history.

The technical speaker, Dr. Robert Aborn of the United States Steel Corp., compared welding of yesterday, today and tomorrow. The first and last parts of the talk were comparatively short, with emphasis placed on welding at the present time.

Dr. Aborn used "Weldability" as his main theme and showed slides to accentuate his points. In this way he was able to show the association of metallurgy to the various zones affected by welding.

The first and last part of his talk was confined to mentioning the various processes used. Mention was made of the possibility of atomic fission in relation to welding.

The A.S.M. and the A.W.S. local Section have tentatively decided to repeat this joint meeting once each year.

Hartford

The Hartford Section held its January dinner meeting on the 20th at the Whitlock Mfg. Co. Cafeteria. Speaker was Charles Bruno, Welding Engineer in the Technical Service Dept. of the Reynolds Co. Mr. Bruno presented a clear-cut, interesting talk on Aluminum. A sound, color of Aluminum movie "Pigs and Progress" was shown and was well received.

Kansas City

On Dec. 16, 1948, the Kansas City Section had a Christmas party. A fine turkey dinner was served, followed by dancing, etc. The party was such a success that it is planned to make it an annual event.

Ray L. Townsend, Mid-Southern District Vice-President and Manager of Tweco Products Co., was the speaker at the January 20th dinner meeting held in the Ad Club. Mr. Townsend's subject "Robbery in the Welding Shop" was accompanied by a film entitled "It Happened Thirty Years Ago." Mr. Townsend gave a résumé of welding since 1916.

Lehigh Valley

R. D. Stout of Lehigh University was the guest speaker at the monthly meeting of the Lehigh Valley Section, which was held Monday, February 7th, at Packard Laboratory, Lehigh University, Bethlehem, Pa. Dr. Stout gave a very interesting illustrated talk on "Welding Metallurgy." He discussed the metallurgical effect of arc welding on weld metal and base metal. He also told of the effect of the welding operation on the yield strength, ductility and notch sensitivity of structural steel and various methods of improving the weld structure.

C. L. Kreidler, Chairman, was in charge of the technical meeting and a Board of Directors meeting which preceded the dinner in Lamberton Hall, Lehigh University.

The Section was honored to have as its guest H. W. Pierce, A.W.S. Second Vice-President.

Long Beach

At the fourth regular meeting of the 1948-49 schedule of the Long Beach Section, Dr. Stephen Seymour gave a most interesting account of the Olympic Games held in London and of his competition in them, as well as the living and economic conditions he found in a trip, after the Games, behind the Iron Curtain into Finland.

His style and fluent delivery, interspersed with humorous incidents which occurred during his trip into Finland and through Europe were very well received.

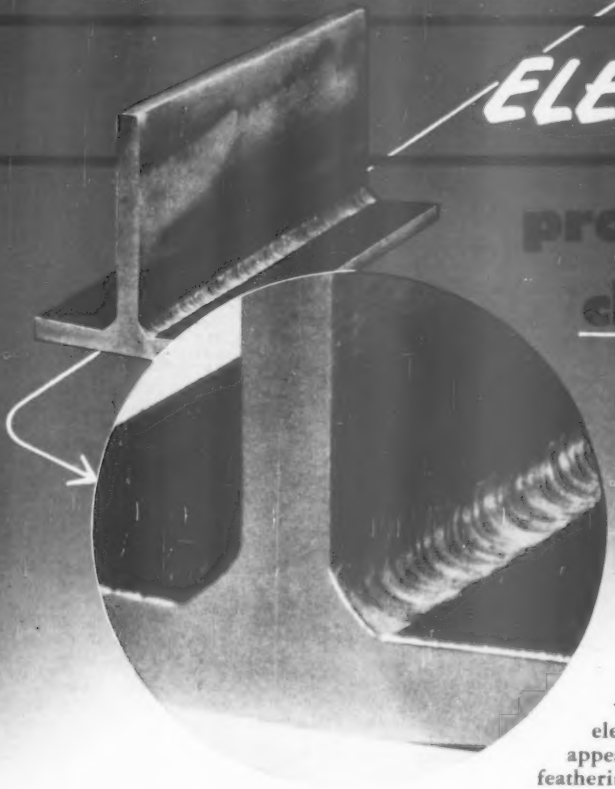
Los Angeles

The Los Angeles Section started its 1949 schedule of monthly dinner meetings Thursday evening, January 20th. One hundred-twelve members and guests were present in the banquet room of Scully's Restaurant to enjoy the dinner and program.

Section Chairman E. O. Williams turned the meeting over to C. E. Swift who introduced the speaker, Dr. W. F. Nash. Dr. Nash, Metallurgist, C. F. Braun and Co., Alhambra, Calif., spoke on the subject, "Why Heat Treat Welds?" Equipment for measurement experimentally of residual stress in simple butt welds was described. Application of this equip-

Kansas City Section Christmas Party

This NEW ARCALOY AC-DC ELECTRODE



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THE *new* Arcaloy AC-DC stainless electrode gives you excellent arc starting performance on *all* types of AC welding equipment, with outstanding welding characteristics on either AC or DC current. It has a smooth, *stable* arc with fine-spray weld metal transfer. Bead is *uniform*, full throated with straight-line feathered edges, and weld metal has complete penetration.

Welder fatigue is reduced . . . slag is easily and *completely* removed with no secondary film, which means less cleaning, grinding and polishing time. Weld has corrosion resistance equal to that of the parent metal with excellent mechanical properties. This all-new Arcaloy AC-DC stainless electrode is available in *all* chrome-nickel analyses . . . is packed in all-steel moisture-proof containers. Write for sample electrodes today!

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decreased to about 1800 miles per hour.

ment to obtain data for plotting of stress patterns was discussed and illustrated with slides. Thoroughly explained next was the mechanism of producing welded-joint stress resulting from welding. Magnitude and location of stresses resulting in a simple butt weld were given. Relief of stresses was described as a necessity where the weldment is to be subjected in service to corrosion or low temperatures.

Particularly interesting were the results of peening which proved that the plate for approximately two inches each side of the welding grooved and particularly the final pass of weld metal must be thoroughly peened to effectively produce stress relief in the weldment. The high level of interest aroused by this talk was exemplified by general discussion which followed.

Louisville

Cares C. Keyser, Welding Engineer, Bethlehem Steel Co., Steelton, Pa., was guest speaker at the January meeting held on the 25th in the Preston Kunz Restaurant. His subject was "Maintenance Welding."

After giving a brief history of maintenance welding, Mr. Keyser used lantern slides to illustrate many of the welding problems successfully solved in the maintenance of equipment for a steel plant. Of particular interest were his pictures and descriptions of the development of the submerged-arc process for building up large engine shafts and the ring grooves on the pistons.

After the discussion following Mr. Keyser's talk a film was shown, "Streamlining Steel," which showed all the steps of steel manufacture from the ore to finished products.

A Dutch Lunch was served at the end of the meeting.

Mahoning Valley

A joint meeting of the A.W.S. Mahoning Valley Section and the Warren Chapter of the American Society for Metals, was held on Thursday, January 20th, at El Rio Restaurant, Warren, Ohio.

More than a hundred heard George Richardson, Welding Engineer, River Works, General Electric Co., Lynn, Mass., talk on the welding and fabrication of aircraft gas turbines. A colored film prepared especially for General Electric by the Walt Disney studios, entitled "Jet Propulsion" was shown. Slide views of all principal types of U. S. Air Force jet aircraft were also shown and described.

Mr. Richardson in his paper emphasized the important part played in jet engine construction by the various welding processes.

Maryland

The January 21st meeting of the Maryland Section was very well attended as one might expect when it is considered that Dr. G. E. Claussen of the Reid-Avery Co. in his very thorough manner discussed the subject "Shrinkage Stresses in Welding." Dr. Claussen, with the aid of slides, explained the reasons for shrinkage stresses pointing out that the simplest stress pattern would be stresses in one dimension; however, stresses are made also in two or three dimensions. The stress characteristics of material were expressed in terms of the stress strain diagram and the harmful effects of welding stresses were also called to the attention of those in attendance. To complete a discussion of welding stresses, methods of reducing or eliminating welding stresses were also discussed, which methods consisted chiefly of thermal stress relief and mechanical work.

Topics for future meetings are as follows: March 18th—"Metallurgical Considerations in Arc Welding;" April 15th—"What to Gas Weld and How."

Michiana

The Michiana Section held its January meeting in South Bend on the 20th. Walter J. Campbell, district welding specialist of the General Electric Co., Atlanta, Ga., talked on "The Problems Behind Inert-Arc Welding." His talk, which was illustrated with slides, touched on a number of the problems which had to be solved before inert-arc welding became of commercial importance.

One problem which required considerable work before the process could be widely used was torch design. Three circulatory systems, electricity, cooling water and the inert gas, must be coordinated so that adequate capacity and ample insulation are combined in a torch light enough to be handled for long periods of time without undue fatigue on the operator.

Another typical problem was that of arc stabilization on a.-c. machines. When welding aluminum, magnesium and other materials having refractory oxides with direct current it is necessary to use reverse polarity. This, however, causes undue heating of the electrode. This heating can be minimized by using alternating current, which has one half of the cycle reverse polarity, the balance being straight. But these same oxides cause a partial and erratic rectification of the current which makes the arc very unsteady. The arc can be stabilized by impressing an outside d.-c. voltage to counteract the rectification, or to put series capacitors in the circuit.

When technical problems are involved, inert-arc welding possesses the following advantages: operator training is relatively easy, warpage is reduced to a minimum due to the very narrow heat band, there is practically no spatter and no flux is needed nor slag produced.

Milwaukee

C. B. Voldrich, Chief Welding Engineer, Battelle Memorial Inst., Columbus, Ohio, was the speaker at the January 28th dinner meeting. His subject was "Weldability of Steels."

Most of Mr. Voldrich's talk was devoted to an explanation of the causes and means of preventing cracking, especially in hardenable grades of steel. It was explained that cracking is not due solely to the presence of martensite. It is possible to have martensite without cracks developing, but in general the reverse is not true in the hardenable steels. Hydrogen dissolved in and retained by the austenite down to room temperatures is the real cause of the cracks. When the retained austenite changes to martensite the hydrogen is released and caused the cracks to develop.

The remedy for such cracking is to use lime-ferritic electrodes or change the specification to a lower carbon content.

The first of the annual series of educational lectures was given on January 17th when L. E. Grant of the Milwaukee Road discussed the Evolution of the Welded Freight Car. On January 24th Don Wilson, a member of the Milwaukee Section and owner of a welding job shop, presented a very interesting and helpful discussion of job-shop problems with special emphasis on tool and die repairs, a field in which Mr. Wilson has specialized. Some of the experiences in job shop work were amusing as well as interesting. This talk, along practical lines, was very well received.

The third meeting was addressed by Erwin Brekelbaum of the Harnischfeger Corp., also a member of the Section. He discussed "Fabricating Structural Shapes" in a very illuminating manner. One of his main points was the tendency to overweld all sorts of weldments. Emphasis was also placed on selecting the proper size of welding rod for various types of joints and sizes of welds.

All sessions have been attended by about 250 men, ranging from welders to management personnel. The question period following the lectures indicated that these talks by local members are furnishing information of value and interest to local industries.

Nashville

A business dinner meeting was held on January 28th in the Maxwell House Hotel. Two films were shown. "So This is Aluminum" was shown through the courtesy of the Aluminum Company of America, and "New Horizons in Welding" was shown through the courtesy of the Harnischfeger Corp.

New Jersey

"Rockets" was the subject of a talk presented before a joint meeting of the New Jersey Section of the A.W.S. and the New Jersey Division of the Metropolitan Section of the A.S.M.E. at the Essex House, Newark, on January 18th.

Lovell Lawrence, noted rocket authority and President of Reaction Motors, Inc., Dover, N. J., gave a most informative talk on rockets and rocket-driven aircraft. Some interesting facts were outlined regarding the V-2 rocket, which was used as an example of this type of power plant. This rocket, which is about 42 ft. long, took off with roughly 5 tons of fuel, which it consumed in about 70 seconds. At the end of this period, an altitude of about 20 miles had been reached, and the speed was 3600 miles per hour. Momentum then carried the rocket to about 70 miles altitude, at which point the speed had

decreased to about 1800 miles per hour. The rocket motor used on these weapons developed the equivalent of about one-half million horsepower.

The impact of these rockets was terrific because of their high velocity, and they penetrated deep into the ground. As a consequence, although their warhead carried only about one ton of explosives, the destructive effect was much higher than a normal one-ton bomb.

New York

Meeting jointly for the first time in its history with the Society of Automotive Engineers, the New York Section heard J. A. Randall, Welding Engineer of Ford Motor Co., Dearborn, Mich., speak on "Welding Applications in Automotive Construction" at the Hotel Statler on Thursday, January 20th. Mr. Randall pointed out that practically all welding processes are used in making an automobile, but stressed that the resistance welding process is best adapted for the welding of sheet metals parts. He described the requirements of resistance spot-welding machines for this work and explained how the Ford Motor Co., has been able to design such machines to fit into the production line. In most cases, it has been possible to integrate the welding machines with the stamping presses so that they can start with flat sheet and end up with formed and welded parts without needing any manual handling during the fabrication. Mr. Randall's talk was illustrated with slides showing machines capable of making as many as 300 simultaneous welds using as many as 28 transformers and with production rates as high as 360 parts per hour.

Preceding Mr. Randall's talk, Prof. Edward Creutz, of Carnegie Institute of Technology, gave a brief illustrated talk on the "Construction of a 400 Million Volt Synchrocyclotron." He had slides and motion pictures showing the construction of the coils at the New York Navy Yard, the fabrication of the forged parts at the Homestead Works at Carnegie Institute Steel Co., and the erection of the Synchrocyclotron at the site.

Harvey Earle of United Parcel Service, Inc., a member of the S.A.E., served as Technical Chairman and E. H. Roper, Chairman of the New York Section, A.W.S., conducted the discussion period.

In the accompanying photo are: Harvey Earle, Superintendent of Motor Equipment of United Parcel Service, Vice-Chairman of Transportation and Maintenance Activity of the S.A.E.; Richard C. Long, of Warren Electric Brake Mfg. Co., Chairman of the Metropolitan Section of the S.A.E.; John Randall, Welding Engineer of Ford Motor Co.; Prof. Edward Creutz of Carnegie Institute of Technology; John L. Cahill, New York Naval Shipyard, Chairman of the Program Committee for the A.W.S. New York Section; Edward H. Roper, of Air Reduction Sales Co., Chairman of the A.W.S. New York Section.

January 20 Joint Meeting S.A.E. and New York Section A.W.S.

Niagara Frontier

The Western New York Section is now known as the Niagara Frontier Section.

Northwestern Pennsylvania

A very successful meeting was held by this Section on Wednesday, January 19th, at the General Electric Community Center, Erie. The Erie Concrete and Steel Supply Co., was host at the happy half hour preceding the very excellent dinner. Immediately following dinner and just before the technical session was a demonstration by Earl Thompson of Erie Concrete & Steel Supply Co., of Tempo Tool, a new power-actuated tool for setting studs into steel, concrete, etc.

George T. Motock, Head of Research and Development Dept. of Champion Rivet Co., was the guest speaker. Mr. Motock spoke on the Metallurgy of Arc Welding. After the meeting was dismissed small groups stood around talking over the points brought out in the discussion for fully three quarters of an hour. Mr. Motock requested that the meeting be kept on an informal basis and suggested that at any time any one desiring to ask a question should do so rather than wait until the end of the meeting. This procedure appealed to all those present.

Philadelphia

Regular monthly dinner meeting was held on Monday, January 17th, at the Engineers Club. Robert M. Ney, Manager of Industrial Relations, The Baldwin Locomotive Works, Philadelphia, discussed the subject, "Labor Relations and Wage Rates." Mr. Ney has had a number of years experience in the field of wage and industrial relations and discussed this subject which is of major interest to all.

The usual snack of beer, pretzels and sandwiches was served after the meeting.

Pittsburgh

The January meeting was held on the 19th at Mellon Institute of Industrial Research Auditorium. A Get-Together Dinner was held at the Fairfax Dining Room.

David F. Helm, Senior Fellow, Mellon Institute, discussed "The Development and Use of Hydrogen-Free Electrodes." Mr. Helm described the present commercial electrodes of this type and some of the uses to which they are commonly put. Attention was next turned to the checkered history of their development and finally some discussion was given on the reasons why they work and have become an important class of arc-welding electrodes.

A movie film "Welding on the Farm" was shown through the courtesy of The Lincoln Electric Co.

A special committee meeting preceded the technical session to discuss arrangements for the "Tri-State" meeting on the afternoon and evening of April 29th.

Puget Sound

With an attendance of over fifty, the Puget Sound Section had one of its most successful meetings of the season when a Symposium on Structural Welding Specifications was held, following a dinner at the Engineers Club on January 26th.

The main object of the symposium was

H. Earle *R. C. Long* *John Randall* *E. Creutz* *J. L. Cahill* *E. H. Roper*

to convince the City Building Dept. and the Seattle Building Commission that the latest A.W.S. code for building construction should be adopted in its entirety. Officials of the city building department were invited and were present.

The discussions were divided into three phases; design, operation and procedure, and inspection. The discussion leaders for the three panels were Roy A. Kamb of the Alaskan Copper Works, Alex D. Sweek of Pacific Car and Foundry Co. and Prof. G. S. Schaller of the University of Washington. Each of the panels consisted of three speakers under the direction of the Panel Leader.

The symposium was under the direction of Elmer E. Gunnette, the Northwest Field Engineer of the American Institute of Steel Construction, who very capably organized the program into logical sequences and brought to focus the many advantages the adoption of our code would be to the building construction in Seattle.

After the close of the discussions, the meeting was opened for general questions and many vital points were answered. A resolution was adopted by the meeting to recommend to the City of Seattle that our latest Standard Code for Arc and Gas Welding in Building Construction be written into the City Building Code.

Rochester

The December meeting of the Rochester Section was held on the 20th at the University of Rochester. A semiautomatic welding device known as Linc-weld was demonstrated by William Douglas, Welding Engineer, and Charles Lytton, District Representative of The Lincoln Electric Co. Before the demonstration a talk, explaining the operation, construction and uses of this equipment was presented by Mr. Douglas. Pictures were also shown.

A movie entitled "The Legend of Useppa" was shown as added entertainment.

On January 11th, seventy members and other interested persons attended the first of a series of six lectures to be held in the Engineering Dept. of the University of Rochester. This series is known as the Educational Program of the Rochester Section and deals with the fundamentals of design, materials and welding procedures. William J. Conley, Consulting Engineer, is in charge of the program.

The January 20th meeting was addressed by A. N. Kugler of Air Reduction Sales Co., New York. His subject, "Brazing and Braze Welding," was well presented. Slides were used to amplify his remarks. Mr. Kugler also touched on some of the revisions that were made to the definition of welding terms in order to assist the designer in making proper notations on drawings. Some of the features of the Aircomatic Process were also discussed.

A picture entitled "All American Soap Box Derby" was presented through the courtesy of the United States Rubber Co.

Before the meeting a dinner was held with the American Society for Metals. A. R. Eckberg, Division Superintendent of Engineering and Maintenance, Eastman Kodak gave a very interesting talk on the economic, educational and industrial conditions in England, France and several other countries in Europe that he recently visited.

San Francisco

Russell G. Rhoades, Chief Welding Engineer, The Bechtel Co., presented a paper, accompanied by slides of "On the Job" photographs, on the welding of medium manganese high strength pipe, at the January 24th dinner meeting held at the Engineers Club.

Mr. Rhoades stated that in maintenance of the pipe lines most all problems are a direct or indirect result of the temperature in welding. Without preheating, the pipe, in hand welding, results in failures; this was determined through many tests made in the field and in shops in Arabia. The preheating must be carried on throughout the welding operation. Starting at 135°, results were fair, at 150° good and at 200° results were excellent. Therefore, the "safety margin" is at 135°.

Mr. Rhoades was asked about the use of gamma rays and stated that they would not do a job without them, that gamma rays were used on about 10% of the work.

It was also pointed out that weld deposits became more brittle around large openings in the pipe; therefore, smaller outlets for valves, etc., were being used.

A display of Japanese welding and cutting torches were shown. These were loaned by Bob Badley of the Associated Pipe Line Welders.

South Texas

The dinner speaker at the January 14th meeting, held at the Ben Milam Hotel, Houston, was A. E. Wisler, Section Chairman, who told of his trip to the National Metal Congress in October.

Robert Milligan, Supervising Engineer, Ocean Accident and Guarantee Corp., Ltd., was the technical speaker. Mr. Milligan discussed Sections VIII and IX of the A.S.M.E. Boiler Construction Code. He discussed the problems involved in applying the Code, plus some discussion of cases in the Code interpretations.

Toledo

The Toledo Section will hold an "Arc-Welding Conference," a course in design for welding, on March 22nd, 23rd and 24th in Room 1, University of Toledo. Lecturer will be R. H. Davies of The Lincoln Electric Co., Cleveland, Ohio. Classes will be from 7:00 to 10:00 P.M., and the cost will be $10 for all three nights or $5.00 for any one night.

The outline of subjects will be as follows:

Tuesday, March 22nd, "Fundamentals of Arc Welding." (1) The Welding process (A. C. vs. D. C.); (2) Electrodes (A.W.S. Classifications); (3) Preheat and Postheat; (4) Automatic and Hand-Welding technique.

Wednesday, March 23rd, "Design of Welded Machinery." (1) Approach to Welded Design; (2) Cast-Iron vs. Welded Steel; (3) Factors Controlled by Design; (4) Controlling Distortion in Design.

Thursday, March 24th, "Design of Welded Structures." (1) Riveting vs. Welding; (2) Non-Rigid, Semirigid and Rigid Construction; (3) Codes; (4) Inspection and Qualification of Welders.

Washington, D.C.

Regular monthly dinner meeting was held on January 25th at Pepco Auditorium. Dinner at O'Donnell's Restaurant.

Speaker at the technical meeting was O. R. Carpenter, Director of the Works Control Laboratory of the Babcock & Wilcox Co. Mr. Carpenter's subject, "Control and Inspection of Alloy Welding," was enthusiastically received.

Coffee and sandwiches were served after the meeting.

Western New York

At a recent meeting of the Executive Committee of the Western New York Section, it was unanimously voted to change the name of the Section to the Niagara Frontier Section.

Wichita

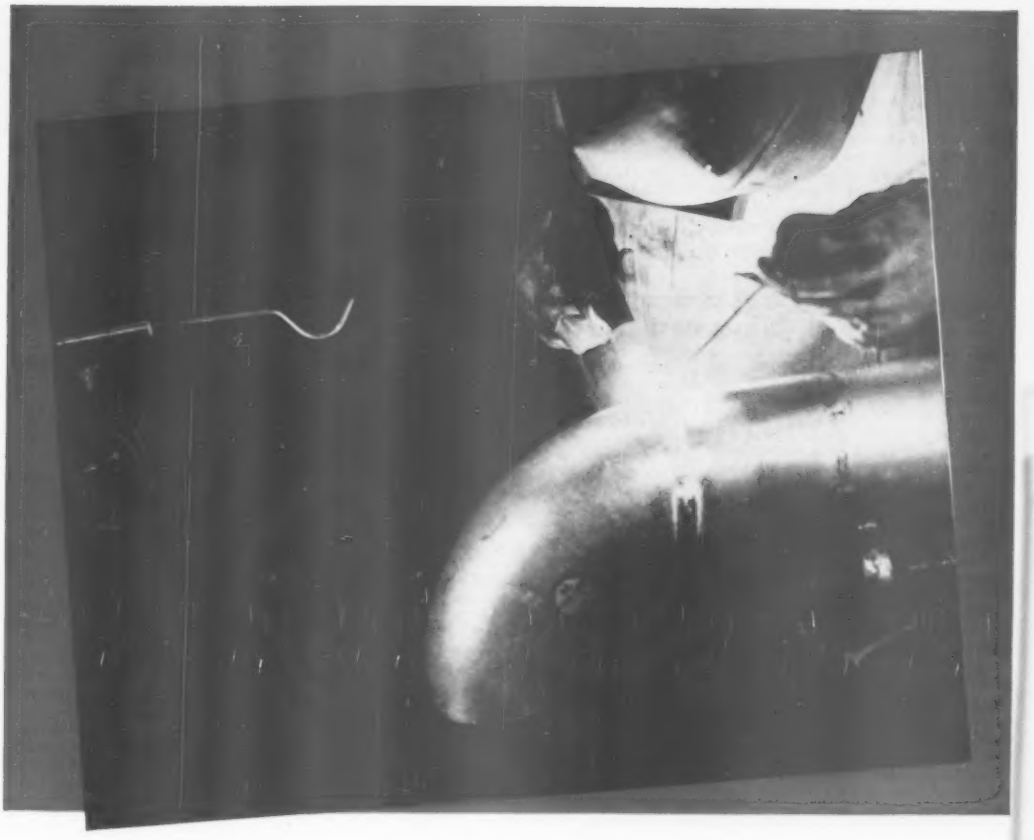
R. L. Townsend, Manager of Tweco Products Co., and Mid-Southern District Vice-President, A.W.S., was the speaker at the January 10th meeting held at the Broadview Hotel. In his subject, "Robbery in the Welding Shop," Mr. Townsend presented vital facts frequently overlooked in maintaining a welding circuit. He placed emphasis on the direct relation of efficient maintenance to quality and production. The visual section of the meeting, developed and presented by Mr. Townsend, was unique, educational and very interesting as well. From welding periodicals of the times he projected comprehensively and clearly articles and advertising pertaining to all phases of the development of welding and current events which affected the welding industry from 1916 up to the present time. A study of progress in the past as a challenge to future progress.

Worcester

Dinner meeting was held on January 31st at the Coronado Hotel, Worcester, Mass. A. A. Barry, of Air Reduction Sales Co., spoke on the subject, "Flame Hardening."

Mr. Barry covered the field of flame-hardening very well, showing slides of the many applications. Pitfalls which cause trouble were brought out and emphasis placed on the use of correct procedures. Selecting the proper equipment and the know-how all add up to a successful completion of any job attempted. Correct types of steels to be flame hardened were very much stressed.

A film showing the forming and fabrication of steel was shown through the courtesy of the Lukens By-Products Div.



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WELDING FITTINGS AND FLANGES

Canadian Welding Society

Montreal Chapter held its fourth meeting of the 1948–49 season on Monday, January 17th. "The Manufacturing, Use and Physical Properties of Bronze Welding Rod" was presented by Kenneth B. Bissell, Research Metallurgist, Bridgeport Brass Co., Bridgeport, Conn., to an enthusiastic audience of about 150. The meeting was preceded as always by a dinner at which time an unusual technicolor film entitled "Metals of the Ages" was shown.

Hamilton Chapter held its fifth meeting of the 1948–1949 series on Tuesday, February 1st, at McMaster University. "Low-Temperature Brazing" was presented by W. J. Stayura, Developing and Engineering Dept., Canadian Liquid Air Co. Ltd., Calgary, Alta.

Kitchener-Waterloo Chapter held its fifth meeting of the 1948–49 series on Wednesday, February 2nd. "Low-Temperature Brazing" was presented by W. J. Stayura.

Niagara District Chapter held its fifth meeting of the 1948–49 season on Thursday, February 3rd. "Low-Temperature Brazing" was presented by W. J. Stayura.

Toronto Chapter held its February meeting on the 7th. "Welding in Oil Refinery, Construction" was presented by L. H. Meredith, Chief Construction Engineer, M. W. Kellogg Co., New York City.

(*Continued from page 278*)

Dollar volume of unfilled orders as of December 31st also totaled about 5 times the backlog in prewar years.

In reviewing the figures for the year, Mr. Wise said:

"There is every indication that the use of resistance welding to cut manufacturing costs of all kinds of products—from automobiles and refrigerators to pots and pans and jewelry—is still far from its peak.

As a matter of fact, it is not unlikely that 1949 will see a further increase in sales of this type of equipment, as the necessity of reducing retail prices becomes more pressing.

"While it is true that some companies have already secured or ordered considerable resistance welding equipment in anticipation of the necessity of reducing manufacturing costs, the keener competitive picture will lead many others to follow suit in order not to be priced out of the market. In addition there is a continuing trend toward the adoption of more automatic machinery requiring relatively little effort and skill for its operation.

"In addition, many industries have only made a small beginning to date in the use of resistance welding."

A.I.E.E. Welding Meeting

The Michigan Section of the AIEE Welding Group will hold a round table meeting on multiple transformer welder design on Thursday, April 28, 1949. The meeting will start at 7:30 P.M. and will be held in the Rackham Memorial Bldg., 100 Farnsworth Ave., Detroit, Mich.

A.S.T.M. Specifications for Steel Piping Materials (December 1948)

This compilation of Standards on Steel Piping Materials, developed, through the American Society for Testing Material's Committee A-1 on Steel, is the sixth edition. This book will provide all those concerned with the production and use of steel piping materials—pipe, castings, bolting, flanges, etc.—with a handy and up-to-date compilation of the A.S.T.M specifications of concern in this field.

These specifications, of which there are fifty, are in very widespread use and the compilation should be of service to the engineer, purchasing agent and other technologists concerned with power plants and similar industrial installations, refineries, distribution of water, gas, oil and the like, and to individuals in every industry where these materials are so important.

Among those specifications listed under the heading "Pipe" are the following: welded and seamless; electric-fusion-welded steel pipe; welded alloyed open-hearth iron pipe; seamless chromium-molybdenum alloy-steel pipe for service at high temperatures and seamless and welded austenitic stainless steel pipe.

Under "Boiler, Superheater and Miscellaneous Tubes," there will be found specifications for lap-welded and seamless boiler tubes; welded alloy-steel boiler and superheater tubes; copper brazed steel tubing; seamless and welded austenitic stainless steel tubing for general service and others.

Copies of this 330-page book, heavy paper cover, can be obtained at $3.00 each from A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

MEMORIAL

Resolutions adopted by the Board of Directors on Jan. 21, 1949

A. M. UNGER

WHEREAS, the AMERICAN WELDING SOCIETY recognizes, in the death of Arthur M. Unger, the loss of an active and enthusiastic supporter of sectional and national affairs of the SOCIETY; and

WHEREAS, he was a leader in engineering in his chosen field of production welding techniques and their application to steel fabrication; and

WHEREAS, Mr. Unger's ability to collect data and present papers of a highly technical nature serves as an inspiration to all welding engineers; and

WHEREAS, his kind, considerate and unselfish cooperation and leadership have contributed much to the advancement of welding; therefore, be it

Resolved, that the AMERICAN WELDING SOCIETY, through its Board of Directors, hereby expresses its sincere appreciation for Arthur M. Unger's services to the SOCIETY; and be it further

Resolved, that this resolution be spread on the records of the SOCIETY and a copy of it be transmitted to Mr. Unger's family.

Above Resolutions prepared by Special Committee,
R. E. McFarland, *Chairman*
E. R. Seabloom

WILLIAM DARRACH HALSEY

WHEREAS, the AMERICAN WELDING SOCIETY has suffered an irreparable loss in the death on Thursday, December 9, 1948, of William Darrach Halsey, valued member of the SOCIETY and many of its important technical committees, and

WHEREAS, he gave unstintingly of his advice, knowledge and skill in the upbuilding of the SOCIETY and its safety standards and codes, and

WHEREAS, his friendly spirit of cooperation and his constructive efforts to improve the effectiveness of the SOCIETY endeared him to the officers and members,

Be it Resolved, that expressions of sympathy and regret be spread upon the records of the SOCIETY and copies thereof be sent to Mrs. Halsey and his family and published in THE WELDING JOURNAL.

Above Resolutions prepared by Special Committee,
H. C. Boardman, *Chairman*
C. W. Obert

WILLIAM F. CARSON

Resolved, That the Board of Directors of the AMERICAN WELDING SOCIETY are deeply affected by news of the death of William F. Carson, a member of the SOCIETY from 1931 to the time of his death. Mr. Carson played a long and active part in the affairs of the Philadelphia Section. He served on the Executive Committee for many years where his counsel, his effort and time, freely given, contributed much to the success of the Section. He was Chairman of the Section during 1934–35 and Treasurer from 1945. He served efficiently and well as Chairman of a Committee which guided the City of Philadelphia authorities on Building Codes as they affected welding.

Resolved, That the Board of Directors in meeting assembled January 21, 1949 extend to Mrs. William F. Carson and others of his family their heartfelt sympathy and the hope that their memory of a beloved life well lived will give them a measure of consolation for their great loss.

Above Resolutions prepared by Special Committee,
R. D. Thomas, *Chairman*
W. W. Barnes

WELDING RESEARCH COUNCIL

of the Engineering Foundation

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American Institute of Mining and Metallurgical Engineers, American Society of Civil Engineers
American Society of Mechanical Engineers, and Society of Naval Architects and Marine Engineers**

Supplement to The Welding Journal, March 1949

Tests of Large Welded-Steel Box Girders

Bending tests at different temperatures

Residual stresses in heavy rigid structures under severe conditions of restraint do not have serious adverse effect on the useful life of such structures under static loads

by Ambrose H. Stang and Bernard S. Jaffe

Abstract

Tests were made to determine the effect of constraint caused by geometrical shape and by differences in temperature on the ductile behavior of welded structures. Four large box girders of identical design were fabricated from fully killed steel from the same heat. The box girders were tested as simply supported beams, one girder being tested at each of the following temperatures: −40, 0, 40 and 80° F. The girders tested at −40 and 0° F. broke with a square type of fracture. The other two girders could not be broken with the available equipment, although deflections at midspan of more than 16 in. were induced on a 22-ft. span. The results of these tests are discussed and compared.

I. INTRODUCTION

The failure of several welded-steel ships during the early part of World War II indicated that problems needed to be solved to place the design of welded structures on a sound basis. One of these problems was the effect of constraint caused by geometrical shape and by differences in temperature on ductile behavior. This constraint is believed to result in multidirectional stresses that are "locked-up" in the structure and not caused directly by applied loads. To study this problem, the Structural Steel Research Committee of the Welding Research Council outlined the tests reported in this paper.

Ambrose H. Stang and Bernard S. Jaffe are connected with the National Bureau of Standards, U. S. Dept. of Commerce, Washington, D. C.

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The box-girder type of specimen was chosen, because it simulates to a large extent the geometry or shape that was suspected of having caused trouble in ships and other welded structures. Four box girders of identical design and all from one heat at the steel mill were fabricated by the Ingalls Shipbuilding Corp., Pascagoula, Miss., and tested as beams, simply supported, in the laboratory of the Engineering Mechanics Section, National Bureau of Standards. The steel was a plain low-carbon, open-hearth steel (A.S.T.M. A-7), fully killed and had good notch-toughness properties at relatively low temperatures. The same sequence of welding was used on each of the girders. Great care was taken to eliminate defects of workmanship during the welding and any possible incipient cracks prior to testing.

One girder was tested at each of the temperatures −40, 0, 40 and 80° F. The girders tested at −40° F. and at 0° F. broke with a square type of fracture. It was impossible to break the other two girders with the available equipment, although deflections at midspan of more than 16 in. were induced during the tests on a 22-ft. span.

II. BOX GIRDERS

1. Design

The details of the box girders are shown in Fig. 1. Each girder consisted of a bottom plate, *A*, $1^1/_2$ in. thick; of two side plates, *B1* and *B2*, each $1^1/_2$ in. thick; of a top plate, *C*, $2^1/_2$ in. thick; and of nine diaphragms, *D*, $1^1/_2$ in. thick. The bottom plate, *A*, was made up of

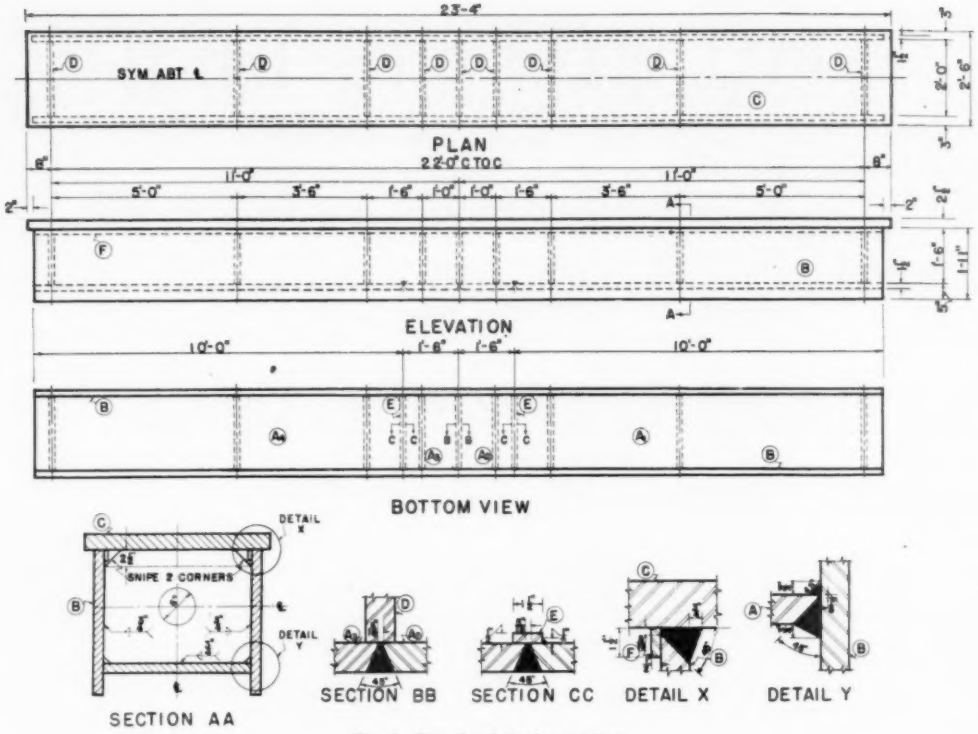

Fig. 1 Details of the box girders

four separate plates—*A1*, *A2*, *A3* and *A4*—with three transverse welds. The diaphragms, *D*, had snipes, 2½ in. on a side, at each of the top corners, and smaller ones at the two bottom corners, as well as a central hole 6 in. in diameter. Backing-up bars, *E* and *F*, were used as indicated in Fig. 1.

The center of gravity of the cross section of the box girder was approximately 10 in. below the top of the girder. The moment of inertia of the section about the neutral surface was about 14,500 in.[4]

2. *Fabrication*

The sequence of assembling and welding of the parts of the girder was the same for each of the girders and was as follows:

Plates *A1*, *A2*, *A3*, *A4*, *B1*, *B2* and *D* were assembled, fitted and tack welded securely by welding one pass on the diaphragm plate, *D*, to the *A* and *B* plates. The outside welds of the two longitudinal butt joints joining the *A* to the *B* plates were made; the center diaphragm was welded and welding of the other diaphragms progressed to the ends. The back-up bars, *E*, were installed on top of the *A* plates for the later transverse welds between the *A1* and *A2* plates and between the *A3* and *A4* plates. The inside welds of the two longitudinal butt joints between the *A* and *B* plates were completed, and the snipes at the bottom of the diaphragms were welded. The back-up bars, *F*, were installed for the longitudinal butt joints between the *B* and *C* plates, and the strain gages were installed on the inside of the girder. The *C* plate was fitted to the *B* plates, and the longitudinal butt joints between them were made and the transverse butt joints between the *A1* and *A2*, the *A3* and *A4* and the *A2* and *A3* plates were made, in that order, to complete the fabrication. The tops of the diaphragms, *D*, were not welded to the bottom of the *C* plate but formed a smooth bearing surface for plate *C*.

If cracks in the weld metal were revealed at any time by magnafluxing, the metal around the crack was chipped out and rewelded before the subsequent welding pass was made.

The welding sequence, as described above, was designed to set up large shrinkage stresses and produce high values of locked-up stresses.

III. COUPONS

Extra lengths of the steel plates, *A*, *B1* and *B2*, were furnished with each girder. Chemical analysis of this material showed percentage contents as follows: Carbon, 0.22; manganese, 0.56; phosphorus, 0.015; and sulphur, 0.026.

From each of these lengths two tensile coupons, in

Table 1—Average Results of Tensile Tests of Coupons

Coupon length parallel to direction of rolling. Each value is the average for the 6 coupons tested at the same temperature

Temperature	Young's modulus	Poisson's ratio (elastic)	Proportional limit (offset 3×10^{-4})	Yield strength	Tensile strength	Elongation in 4 in.	Reduction of area
°F	Kips/in.²		Kips/in.²	Kips/in.²	Kips/in.²	Percent	Percent
−40	29,390	0.273	28.3	[a] 33.9	68.7	39.9	56.1
0	30,010	.280	25.8	[a] 32.8	70.1	34.9	53.4
+40	30,180	.295	22.4	[b] 31.4	67.7	36.6	55.7
+80	28,560	.270	21.3	[b] 30.2	65.6	37.4	53.2

[a] Yield point by drop-of-beam method.
[b] Yield strength, 0.002-offset method.

the direction of rolling, were machined, six for each girder. The coupons were 12 in. long, $1^1/_8$ in. in diameter in a reduced section 9 in. long, and were threaded at both ends to fit the adaptors of the pulling rods.

The tensile tests were made in a horizontal Amsler testing machine, 100-kip capacity, at the same temperature as that at which the corresponding box girder was tested. For those coupons tested at temperatures below 80° F., the temperature was maintained by carbon dioxide ice in an insulated box surrounding the specimen. For temperatures of −40° F. and of 0° F., the temperature was measured by means of two copper-constantan thermocouples attached one to each end of the reduced section of the specimen. A mercury thermometer was used for measuring the temperature for tests at 40° and at 80° F.

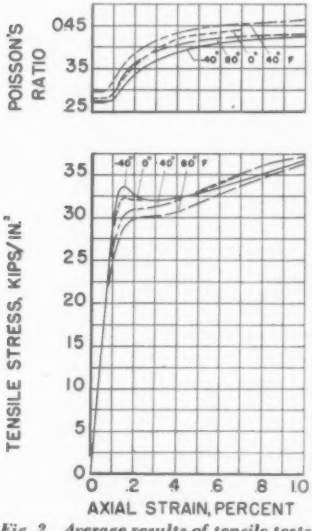

Fig. 2 Average results of tensile tests of coupons

The average results of the coupon tests are given in Table 1.

The axial strains and the transverse strains were each determined by means of two SR-4 bonded resistance wire strain gages (*A5* or *A3*) attached at mid-length of the specimen. Young's modulus of elasticity and Poisson's ratio in the elastic range, and axial strain-stress and axial strain—Poisson's ratio data for plastic strains—were computed from these data. The remainder of the results given in Table 1 were computed in the conventional manner.

The values in Table 1 show that the proportional limit and yield-strength values decreased as the temperature increased. The other values did not appear to be influenced by the temperature.

Figure 2 shows the average values for the stress-strain and Poisson's ratio–axial-strain relations. The latter values did not appear to vary consistently with temperature. In the stress-strain diagram, the stresses at the knee of the curves decreased as the temperature

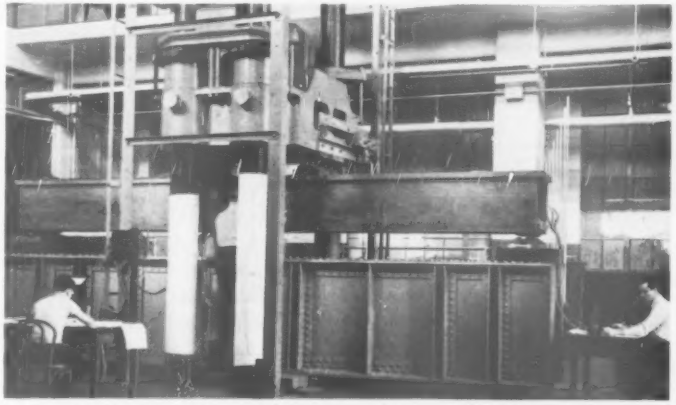

Fig. 3 Box girder in the testing machine, at 80° F., before test

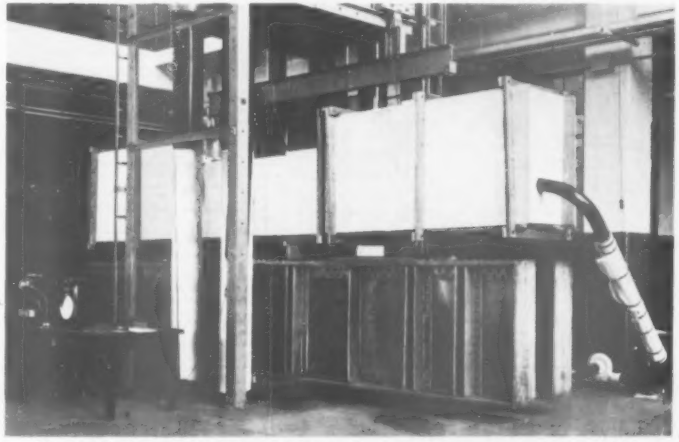

Fig. 4 Enclosure of the box girder for tests at temperatures below 80° F.
Note the frost covered blower and pipes of the forced-circulation system

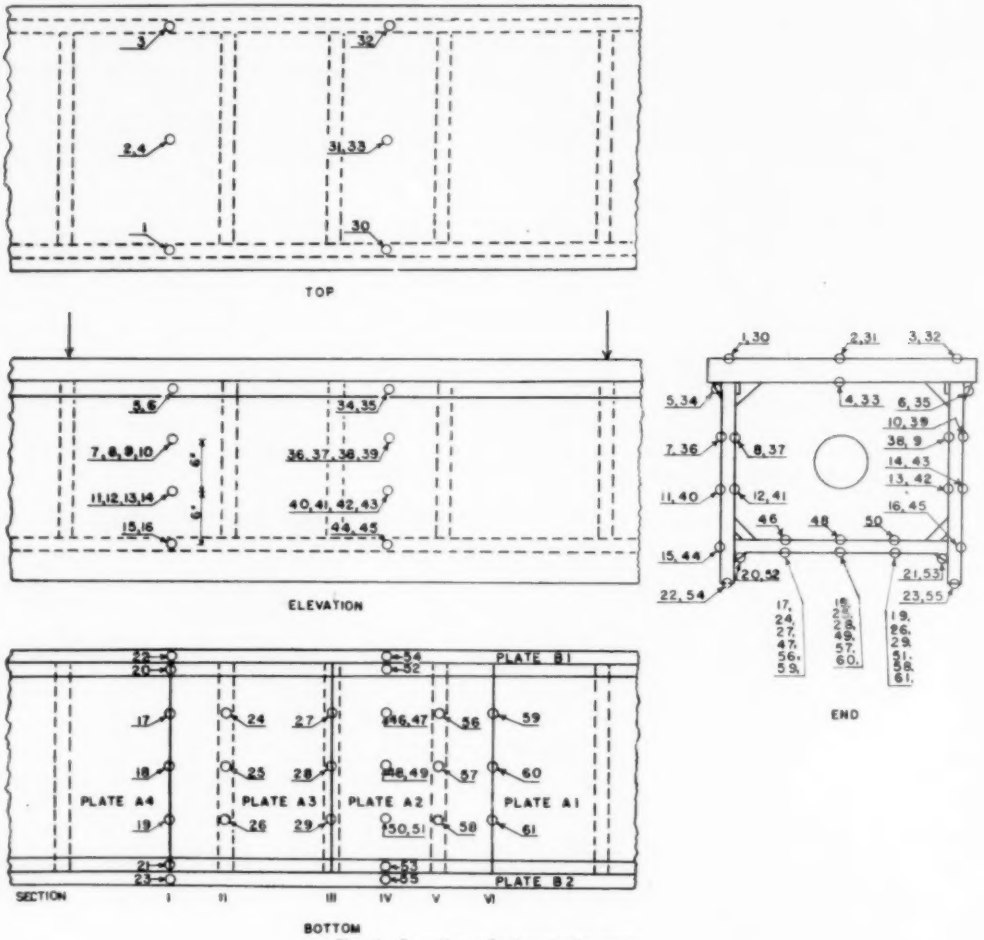

Fig. 5 Location of wire-strain gages

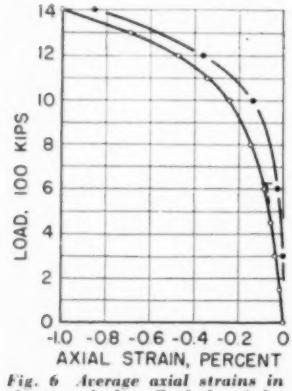

Fig. 6 Average axial strains in the top of plate C of the girder tested at 40° F. (6 gages)

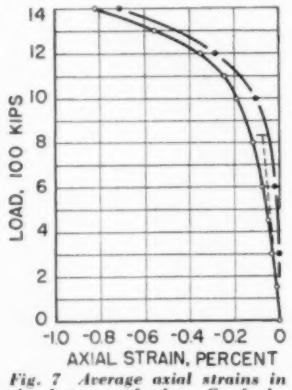

Fig. 7 Average axial strains in the bottom of plate C of the girder tested at 40° F. (2 gages)

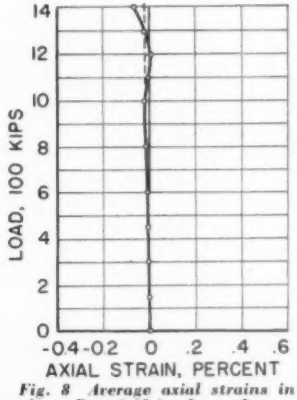

Fig. 8 Average axial strains in plates B at 9.25 in. from the top of the girder tested at 40° F. (8 gages)

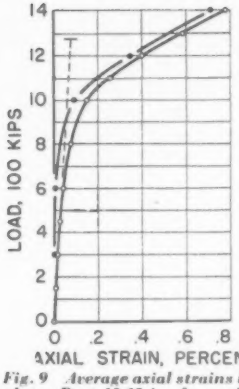

Fig. 9 Average axial strains in plates B at 15.25 in. from the top of the girder tested at 40° F. (8 gages)

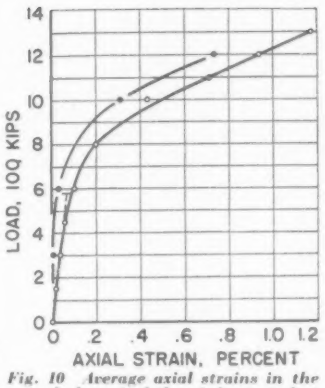

Fig. 10 Average axial strains in the top of plate A of the girder tested at 40° F. (3 gages)

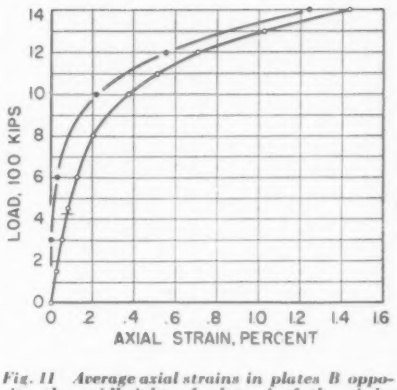

Fig. 11 Average axial strains in plates B opposite the midheight of plate A of the girder tested at 40° F. (4 gages)

increased, but on the later ascending portions of the curves, the temperature effects appear to be negligible.

IV. TESTS OF BOX GIRDERS

1. General

Each box girder was tested as a simple beam, supported on cylindrical bearings on a horizontal span of 22 ft., and loaded by two equal loads, 5 ft. apart and each 8 ft. 6 in. (102 in.) from the nearer support. Figure 3 shows the box girder in the testing machine for the test at 80° F.

For tests at temperatures lower than 80° F. the girder was enclosed in an insulated box and cooled with carbon dioxide ice. To obtain and maintain the low temperature, some of the ice was piled on top of the girder and some placed in the ends of the girder through the holes at the middle of the end diaphragms. Cooling was hastened and regulated by forced circulation through a closed circuit consisting of a blower, pipe to the girder, the girder and a return pipe to the blower as shown in Fig. 4. The temperatures were measured by means of six copper-constantan thermocouples near mid-span. Three thermocouples were on top of plate *C* and three on the bottom of plate *A3*.

2. Strain Gages

The stains at various locations between the lines of load application were measured with SR-4 bonded-resistance wire-strain gages. The locations of the strain gages are shown in Fig. 5. Gages 22, 23, 54 and 55 on the bottom edges of the plates *B* were single gages, *A1* or *A3*. The gages at other locations were rosette gages, AR-1 or AR-2. The nominal gage length was $^{14}/_{16}$ in. for all gages.

For the girder tested at −40° F., the strains were

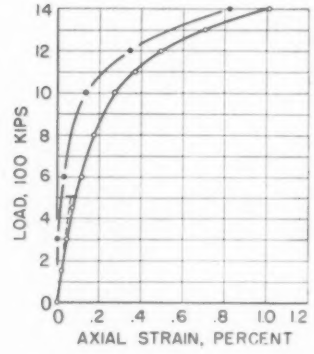

Fig. 12 Average axial strains in the bottom of plate A—not on a weld, opposite a diaphragm—of the girder tested at 40° F. (6 gages)

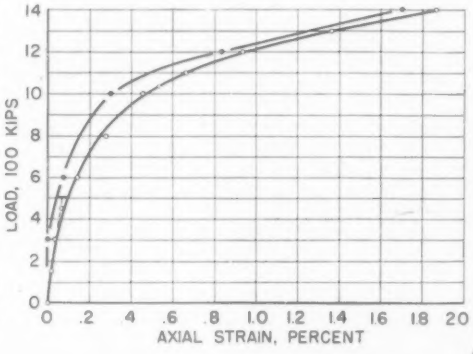

Fig. 13 Average axial strains in the bottom of plate A—not on a weld, not opposite a diaphragm—of the girder tested at 40° F. (3 gages)

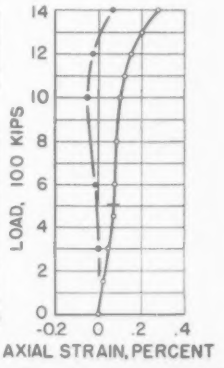

Fig. 14 Average axial strains in the bottom of plate A—on a weld, opposite a diaphragm—of the girder tested at 40° F. (3 gages)

measured with scanning switches and recorders shown in Fig. 4 to the left of the girder. Portable strain indicators were used during the other tests.

3. *Deflections*

The deflection of the girder at mid-span was measured by the taut-wire mirror-scale method. Deflection readings were generally taken as soon as the load was attained and also at the same load, when the strain readings for that load had been completed.

4. *Method of Test*

The girders were loaded in a number of steps, gradually increasing the load each time but relaxing the load completely between increments of loading. Strains were measured at the various loads and at the zero loads after the load had been removed. For the girder tested at 40° F. the load was held for a period at 1200 kips., during which several sets of strain readings were taken, the last set of readings being started 2 hr. and 40 min. after the 1200-kip. load had been reached. A set of readings, when the portable strain indicators were being used, took from 15 to 20 min.

Loading was continued until either the girder was broken or until the middle of the girder was nearly in contact with the supporting girder.

5. *Load-Bending Moment Relation*

From the condition of the tests, the bending moment between the points of load application where the strain gages were located was equal to 51 P-kip.-in. if the total load, P, is in kips.

V. RESULTS AND DISCUSSION

1. *Average Axial Strains*

As was to be expected from the general agreement of the stress-strain curves for the coupons at different temperatures, the load-strain relations for the girders were not much affected by differences in temperature. Consequently, in this report it has seemed adequate to treat mainly the load-strain relations at a single temperature, namely 40° F. The variations for the girder tested at that temperature are similar to those for the other girders tested at other temperatures.

The average strains at a given load for the gages at equal distances from the top of the girder were averaged and have been plotted—for the girder tested at 40° F.—in Figs. 6 to 17. In these figures, the inclined dotted line terminated by a horizontal bar represents the load-strain relation as computed by the ordinary beam theory for the location of the gages under consideration and using the average value for Young's modulus for the coupons, as given in Table 1 for this girder. The load at the end of this line corresponds to the average proportional limit stress from Table 1.

Tensile strains are plotted to the right. Compressive strains are plotted to the left and indicated as negative. The observed average strains due to the load are shown as open circles. The sets, remaining after the load was removed, are shown as solid circles.

In general, it may be noted in these figures that the load-axial strain curves practically coincide with the theoretical lines for loads in the lower elastic range. The observed strains at the proportional limit values were generally larger than the computed values. The set values for the greater loads are generally a very large fraction of the corresponding strain-under-load values.

The load-strain curves for gages on the bottom of plate A, Figs. 12 to 15, are of especial interest. For the gages not on a weld, Figs. 12 and 13, the strain was much less in the plastic range for the gages that were opposite a diaphragm, Fig. 12, than for those not opposite a diaphragm, Fig. 13. These strains in the bottom of plate A not on a weld were, in the plastic range, much larger than for the gages that were on a

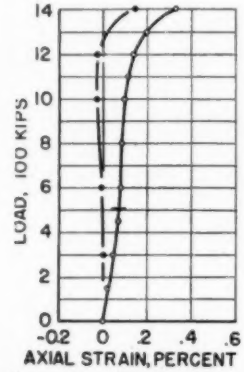

Fig. 15 Average axial strains in the bottom of plate A—on a weld, not opposite a diaphragm—of the girder tested at 40° F. (6 gages)

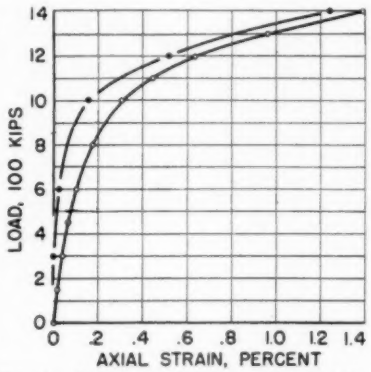

Fig. 16 Average axial strains in the welds between plates A and B of the girder tested at 40° F. (4 gages)

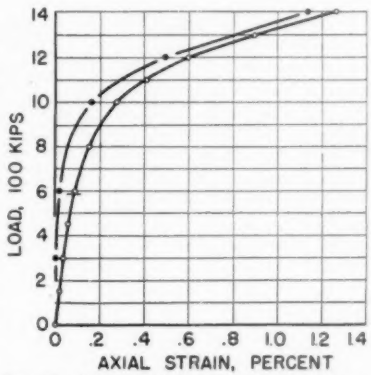

Fig. 17 Average axial strains in the bottom edge of the plates B of the girder tested at 40° F. (4 gages)

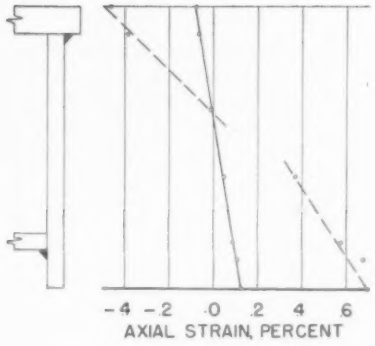

Fig. 18 Average axial strains vs. gage location, on plates B and C for loads of 600 kips (solid line) and of 1200 kips (dash line)

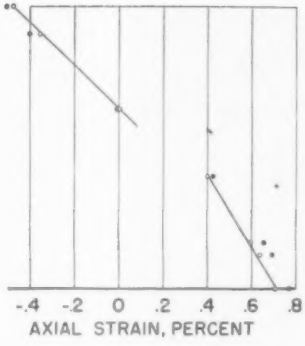

Fig. 19 Average axial strains vs. gage location for a load of 1200 kips on the girder tested at 40° F.

Open circles are for readings started as soon as the load was reached; solid circles for readings started 2 hr. 40 min. after the load was reached

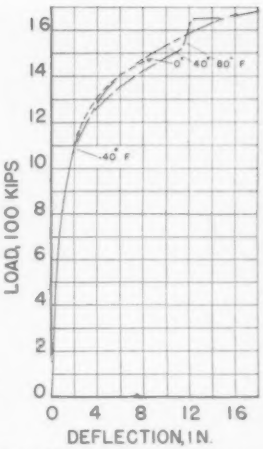

Fig. 20 Deflection at mid-span for the girders

weld, Figs. 14 and 15. This same phenomenon may be observed during the tensile test of a steel coupon, which has a transverse weld at mid-length. For some grades of steel and of weld metal, the weld metal reduces in section very little, after the yielding of the plates commences, whereas there is a visible reduction in section of the adjacent plate material. The permanent sets for the gages on a weld were negative for loads up to more than 1200 kips. The difference between the load-strain and the load-set curves, at a given load, is, however, very nearly equal at each of these four locations.

The load-axial strain data, obtained during these tests, throws some light on the question as to whether sections plane before loading remain plane after a load is applied. To answer this query, the average axial strains on plates *B* and *C* for all the girders have been plotted in Fig. 18, against the location of the gages on the girder. The solid line is for the 600-kip. load (average for four girders). This line cuts the zero-strain line at the computed location of the neutral surface and all the values are close to this one line. The dash lines have been drawn through the average values for the 1200-kip. load (average for three girders, since the girder tested at −40° F. did not attain this load), and certainly no one line can be drawn through these values so that the strain values at different distances from the top of the girder are close to it. It seems that for these box girders, with diaphragms at various locations along their length, plane sections did not remain plane under loads in the plastic range.

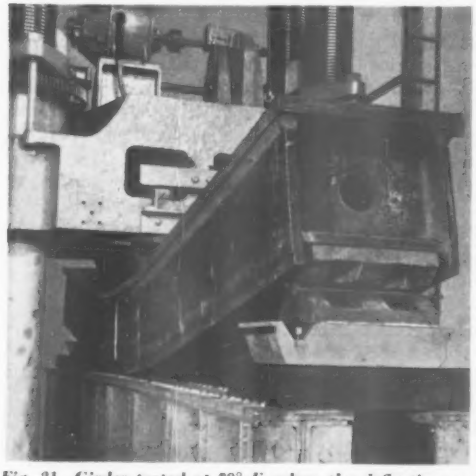

Fig. 21 Girder tested at 80° F. when the deflection was 18.06 in.

Fig. 22 Fractured surface of the girder tested at —40° F.

Fig. 23 Fracture at mid-span of the girder tested at 0° F.

It was suggested that this apparent warping of an initially vertical plane section was due to the timing under which the gage readings were taken and that if the load—while in the plastic range—were applied for some time before the reading of the gages was started, the sections would be found still plane. The procedure had been to start taking the strain readings about as soon as the load was reached. To study this effect, during the testing of the girder at 40° F., several sets of readings at a load of 1200 kips. were taken, as has been stated. The average strain values from the readings, started as soon as the load was reached, are plotted in Fig. 19 against the location on the girder as open circles. As for Fig. 18, no one line would represent the data well. The strain values from the readings, started 2 hr. and 40 min. after the 1200-kip. load had been reached, are plotted as solid circles in Fig. 19. They show the commonly observed phenomenon of continued yielding of both tension and compression with a consequent still greater warping. It may be noted that the gages under consideration were not located in the plane of a diaphragm (See Fig. 5).

2. *Deflections at Mid-Span*

The load-deflection curves for the girders are shown in Fig. 20. The temperature apparently had no significant influence on the deflection. The arrowheads indicate the load and deflection at the failure of the girders, which were tested at −40° and at 0° F. These failures were on the rising portion of the curve. The results indicate that the restraints induced by the welding of the ductile plates were of such magnitude as to result in rather brittle failure for temperatures as high as 0° F. The temperature of 40° F. was evidently not low enough to induce failure.

The break in the load-deflection curve, Fig. 20, for the girder tested at 80° F., at a deflection of 11.56 in. and a load of 1530 kips. was due to the fact that during the test of this girder, the test was stopped at this deflection when the middle of the girder nearly came in contact with the supporting girder. During this first portion of the test, the supports for the girder were as shown in Fig. 3. Since fracture had not occurred, the box girder was taken out of the machine, the cylindrical supports were raised about 6 in. by the blocks shown in Fig. 21, and the girder was again placed in the testing machine. The second portion of the test was made 7 days after the first portion of test. On reloading, the load-deflection curve between loads of 1530 and 1650 kips. was not a smooth continuation of the load-deflection curve obtained during the first portion of the test but was much steeper. After the load of 1650 kips. had been attained, the deflection increased with little increase in load until the curve became practically a continuation of that obtained during the first portion of the test. The moving of the girder and the time between the two portions of the test evidently contributed to bringing about some change in the load-deflection relation for this girder, which had already been subjected to plastic yielding.

Table 2—Summary of Flexural Tests of Box Girders

Temperature	Maximum load	Maximum moment [a]	Modulus of rupture [a]	Maximum deflection
°*F*	*Kips.*	*Kip.-in.*	*Kips./in.*^{2}	*in.*
−40	[b] 1,165	80,400	63.1	2.45
0	[b] 1,476	75,300	79.9	8.83
+40	[c] 1,670	85,200	90.4	16.16
+80	[c] 1,685	85,900	91.2	18.06

[a] As computed from the load at failure or from the maximum load that was reached.
[b] Load at failure.
[c] Maximum load that was reached. No failure.

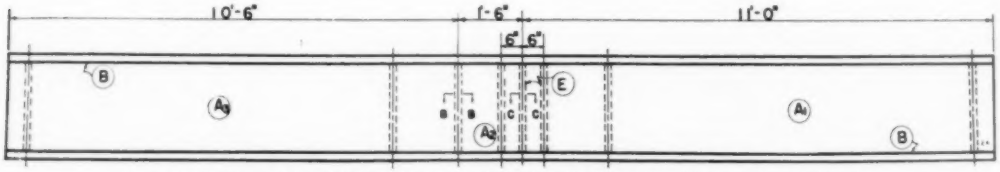

Fig. 24 Bottom view of the girder of semikilled steel (Other details are shown in Fig. 1)

3. *Maximum Loads*

Table 2 gives a summary of the maximum values obtained at the failure of the girders that broke during the tests at −40° and at 0° F., as well as the maximum values reached during the other two tests when failure did not occur.

The fractured surface of the girder tested at −40° F. is shown in Fig. 22. The fracture was partly in the weld between the plates *A1* and *A2* and partly in plate *A2*. The fracture at mid-span of the girder tested at 0° F. is shown in Fig. 23. This fracture took place in plate *A2* and not in any portion of a transverse weld. Figure 21 shows the girder tested at 80° F. with deflection of more than 18 in.

VI. SUMMARY

Bending tests were made on large welded-steel box girders at temperatures of −40, 0, 40 and 80° F. Tensile tests of the material at these temperatures showed that the steel was as ductile at the lowest as at the highest temperature. Due to the constraint induced in the girders by the welding, square types of fracture occurred in the girders tested at −40° and at 0° F. but did not occur in the girders tested at 40° and at 80° F.

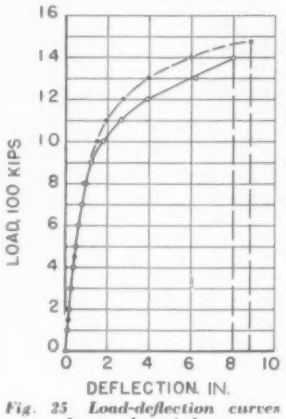

Fig. 25 Load-deflection curves for two box girders

Solid line, open circles, a girder of semikilled steel tested at 80° F. Dash line, solid circles, a girder of fully killed steel tested at 0° F.

VII. APPENDIX

A fifth box girder, the material of which was a semikilled steel instead of the fully killed steel used in the other four girders, was also tested at room temepature, about 80° F. This box girder was the same size as the others and differed from the design shown in Fig. 1 only as follows:

The two diaphragms, *D*, were omitted; the bottom, *A*, plate was made of three plates with two transverse welds. Figure 24 shows the details of the bottom view of this girder of semikilled steel. It failed with a square type of fracture after being tested in a manner similar to that for the other four girders.

Table 3—Results of Flexural Tests of Two Box Girders

Girder steel	Semikilled	Fully killed
Temperature of test, ° F	80	0
Maximum load, kips	1,397	1,476
Maximum moment, in.-kips	71,200	75,300
Modulus of rupture, kips/in.^{2}	75.6	79.9
Maximum deflection, in.	8.00	8.83
Energy to failure, kip-in.	8,350	10,000

The load-deflection curve for the girder of semikilled steel is shown in Fig. 25 by open circles and solid line. The load-deflection curve for the girder of fully killed steel, which was tested at 0° F., is also shown in this figure, by solid circles and dash line. The results of the tests of these two girders are compared in Table 3.

These results show that the girder of fully killed steel tested at 0° F. was superior in the load properties, as given in Table 3, to the girder of semikilled steel, which was tested at 80° F.

FLOW AND FRACTURE OF METALS

The scientific phenomena involved in the flow and fracture of metals has engaged the attention of some of the ablest scientists in the world in recent years. The problem is particularly important in welded structures where the monolithic character of a welded assembly brings into play stresses of a three-dimensional character. Stress concentrations, temperature, quality of steel, rates of loading, degree of constraint, are only a few of the many complex variables involved in the thorough understanding of the subject. In order to make available to engineers and research workers the best existing information, two comprehensive reviews were prepared on the subject. One of them was made by Major Holloman under the supervision of the Welding Research Council and the other by Dr. Gensamer and his associates for the U. S. Navy. Each of these are already available in book form at $1.00 per copy. Orders may be placed for either or both of these books at once. Address orders to:

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Effect of Residual Compression on Fatigue

The effect of residual compression on the propagation of a fatigue crack in notched aluminum alloy

by D. Rosenthal, G. Sines and G. Zizicas

Summary

In a previous work it has been shown that in mild steel notched specimens the propagation of a fatigue crack could be slowed down appreciably by submitting the metal around the notch to a residual compression. This treatment failed to produce the expected result when applied to a stress-relieved aluminum alloy. From the analysis of the results it has been concluded that the reason for this failure lay in the nature of the material employed. Further experiments are contemplated to ascertain whether the stress relief heat treatment or the nature of the alloy is the determining factor.

INTRODUCTION

ONE of the problems which appears to be especially important to the aircraft industry is the improvement of the fatigue characteristics of welded members, particularly those made of aluminum alloys. It is well known that almost every type of welded joint possesses some sort of surface discontinuities, such as notches, which act as stress raisers and which often cause a premature failure. In a broader sense these notches may be regarded as incipient cracks. The problem, then, is to investigate under what conditions the propagation of an incipient fatigue crack can be stopped altogether or, at least, slowed down to such a degree that a noteworthy increase of the design stress may be contemplated. In a previous work it has been shown[1] that in mild steel notched specimens the propagation of a crack under a given fatigue load could be slowed down in the ratio of 1 to 4 by submitting the metal around the notch to a residual compression. In discussing this result the authors surmised that the residual compression would benefit mostly those materials which possessed low fatigue limit as compared to their yield point. On the strength of this argument the aluminum alloys should be especially promising. A program of an investigation, therefore, was developed, the first results of which are reported in this paper.

EXPERIMENTAL PROCEDURE

A. Specimens

The X-ray diffraction technique, which was used in this work for the determination of the residual stress, has put certain limitations on the kind of material to be employed. To achieve the desired accuracy in the stress measurement it was desirable to have a grain size corresponding to the ASTM austenitic grain size No. 5 or higher. This requirement was met satisfactorily in the aluminum alloy 61S whose chemical analysis and mechanical characteristics as-received are given in Table 1. Upon inspection with X-rays the as-received stock revealed a certain amount of cold work, and some residual stress was present due undoubtedly to rolling. Either of these factors could have an unpredictable effect on the results. It was, therefore, deemed necessary to remove this effect and deal with a virgin, stress-free material. The following treatment was found to accomplish the desired result: heating at 600° F. for one-half hour followed by cooling in the furnace at an average rate of 120° F. per hour. Prior to the treatment the specimens were machined according to sketch, Fig. 1. But for minor changes the type of specimen was the same as that used for mild steel in the previous work.[1] The mechanical properties of the stress-free material are shown also in Table 1. They differ considerably from the as-received ones which are the usable characteristics of this material. This circumstance must be kept in mind when trying to apply the results obtained in this work to the commercial product.

B. Setting Up of Residual Compressive Stress

Three sets of specimens were prepared. The first set was stress free. The two others contained residual stresses of two different magnitudes. The residual stress was produced by loading stress-free specimens in tension slightly beyond the yield point. On yielding, the metal near the notch undergoes a greater permanent extension, because of stress concentration, than the rest of the notched section. Therefore, it is subjected to a residual compression by the less extended fibers when the load is removed. The magnitude of the residual stress can be varied by changing the value of the maximum load to which the stress-free specimens are submitted. In one series the average stress in the notched section was brought up to 0.83 yield point, thus entailing yielding only around the notch, whereas in the

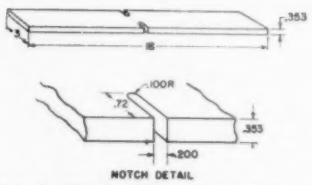

Fig. 1 Sketch of the fatigue specimen

Table 1—Composition and Mechanical Characteristics of the Aluminum Alloy 61S

I. Chemical Analysis, %*		
Cu	0.25	
Cr	0.25	
Si	0.6	
Mg	1.0	
II. Mechanical Characteristics:		
	Treatment	
Characteristic	As-Received	Stress Relieved†
Yield Point, 0.2%, psi.	40,000	16,300
Tensile Strength, psi.	45,000	25,700
Elongation, %	12	20
Endurance limit, psi.	13,500	N. D.

* Supplied by the manufacturer.
† Determined in the present work.

D. Rosenthal, G. Sines and G. Zizicas are with the Dept. of Engineering, University of California, Los Angeles, Calif.

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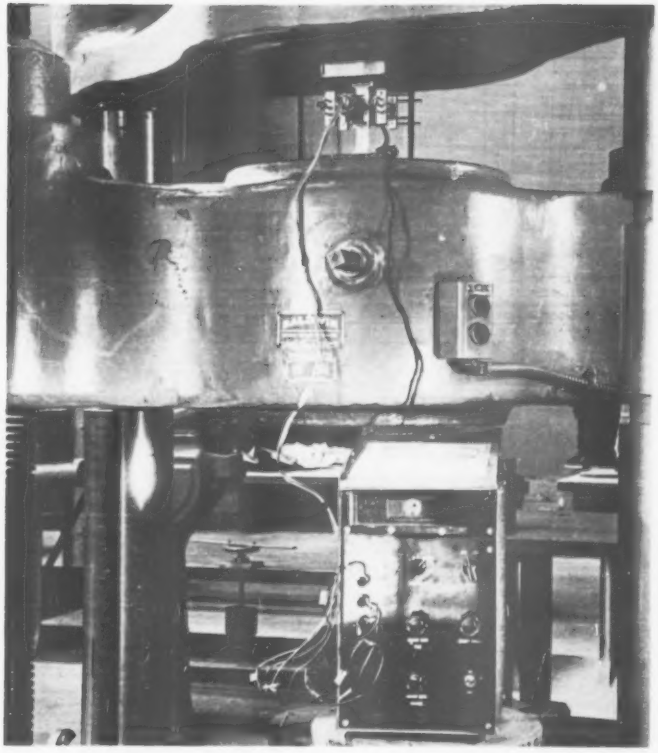

Fig. 2 Tensile specimen with a pair of recording extensiometers

other series this stress reached a value which was 15% higher than the uniaxial yield point. In order to have an idea about the amount of deformation produced in both cases near the notch, a 1/c-in. gage was attached 0.09 in. away from the notch to a pilot specimen which was pulled at the same rate as the other specimen until the gage failed. The centering of the specimen in the testing machine was controlled by means of three bonded gages placed outside the notched section as seen in Fig. 12. For the sake of comparison stress-strain diagrams of unnotched specimens also were taken up to the yield point by means of a special pair of recording extensiometers, Fig. 2.* In order to minimize the effect of eccentric loading reported in the previous work,[1] the specimens were turned 180° around their longitudinal axis after the first application of load and then reloaded. The load was applied at a rate of 4000 lb. per minute. The stress pattern produced by this procedure proved to be fairly symmetrical and consistent for all specimens of the same series.

C. X-ray Stress Measurements

In order to evaluate correctly the influence of residual compression on fatigue, a nondestructive technique was required that would not only measure the residual stress locally, but also follow up any change in its magnitude during the fatigue testing. So far the X-ray diffraction technique alone has been able to accomplish this twofold purpose successfully. The main features of this technique as applied to aluminum alloys have been described elsewhere.[2] Therefore, only a few details which pertain to the present work will be mentioned briefly.

The X-ray radiation was supplied from a sealed hot cathode-tube with a copper target connected by means of a shielded cable to one of the terminals of a high-tension transformer of a standard radiographic unit, Fig. 3. The camera, Fig. 4, used for the recording of the X-ray beam which was diffracted from the specimen, was of the back reflection type designed and developed at M.I.T.[3] A mask placed in front of the camera made it possible to have three different diffraction patterns recorded on the same film. A thin layer of tungsten (W) powder dusted onto the surface of the specimen supplied a reference diffraction ring on the film for the purpose of calibrating the film-to-specimen distance. As shown elsewhere,[2] by taking two photographs, one with the X-ray beam normal to the surface of the specimen and one with the X-ray beam inclined at 45° to the surface, the stress contained in the plane formed by the normal and the 45° directions can be computed by means of the following formula:

$$S = K (\Delta_1 - \Delta_{45})$$

Here, Δ_1 is the spacing measured on the film between the W and specimen's diffraction lines, in the normal exposure, Δ_{45} is the same spacing measured in the oblique exposure on the most sensitive side of the film,[2] both corrected to the same value of the diameter, D_W, of the W diffraction ring. K is a constant which for D_W = 50 mm. has a value of 12,400 psi, for each millimeter difference between Δ_1 and Δ_{45}, according to a calibration made by

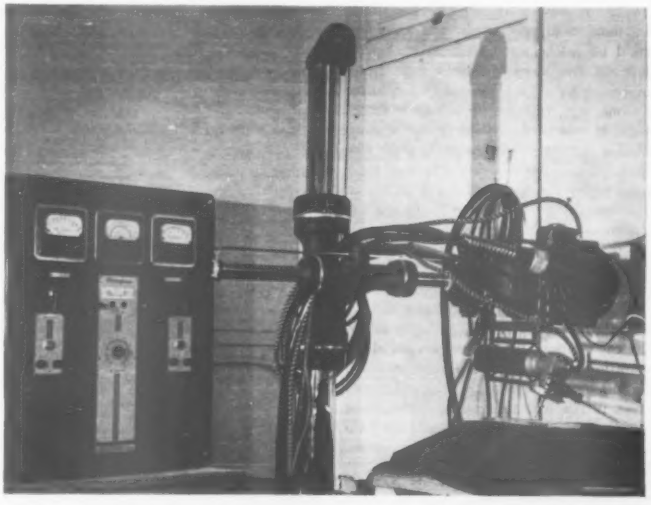

Fig. 3 X-ray diffraction tube connected to a standard radiographic unit

* Built at the Engineering Shop of U.C.L.A.

Frommer and Lloyd.[3] In the present work the values of Δ_1 and Δ_{45} were measured close to 0.05 mm., thus entailing a probable error of about ±1200 psi. in the residual stress measurements.

Since the specimens were stress relieved after machining no surface preparation was necessary for the taking of X-ray diagrams. A lead shield containing 0.07-in. diam. holes was laid on the surface to define exactly the location and size of the spots to be investigated. The distance of the holes from the edge of the notch was measured to within ±0.005 in.

FATIGUE TESTING

As in the previous work the fatigue tests were performed in the Rayflex machine which subjected the specimen to a reverse bending, Fig. 5. The specimen was vibrated at its natural frequency, and it was supported at the nodes by two narrow rubber strips. Since the vibration was set by means of electromagnets acting on both ends of the specimen, the latter was provided with special end plates made of mild steel, Fig. 5.

The machine is tuned to the natural frequency of the specimen by means of an oscillating circuit, and the desired amplitude is obtained by varying the energy output of the circuit.

A special mild steel yoke attached to the specimen, Fig. 6, insured the stability of the amplitude and frequency by acting on the magnetic field of two pick-up coils connected to a control circuit.

The amplitude of vibration was controlled to within ±$^1/_{1000}$ in., which as shown by calibration represented ±200 psi. of the nominal fiber stress in the notched section. The machine was designed to stop automatically whenever the specimen was out of time, as a rule, at the onset of a crack. However, as long as the crack remained relatively small, the specimen could be reset in vibration at a slightly different frequency. Since the machine happened to stop occasionally for other reasons, e.g., because of voltage fluctuations, it was necessary to devise a more reliable criterion of failure. This was accomplished by carrying the test to a point where the specimen could no longer be maintained in vibration.* This point was considered to be indicative of the failure of the specimen, and the number of cycles recorded up to this point was taken as the number of cycles at failure.

Since the specimen was notched, a special calibration test was set up to establish the relation between the amplitude of vibration and the stress in the notched section. The details of this calibration are given in the Appendix. For convenience the amplitude of vibration has been calibrated in terms of the nominal fiber stress.

* Fortunately, after a significant change in frequency had occurred the additional number of cycles preceding failure was only a small fraction of the total number of cycles. In other words, the criterion was not too critical.

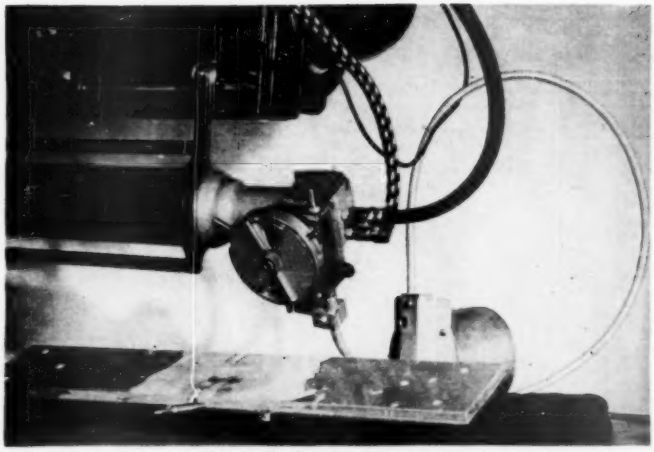

Fig. 4 Back reflection camera

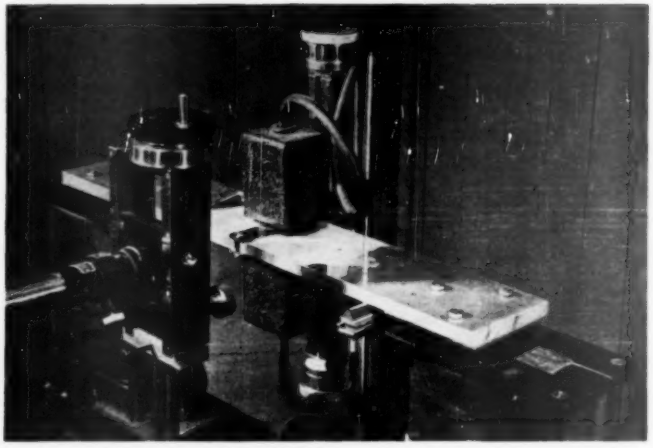

Fig. 5 Rayflex fatigue tester

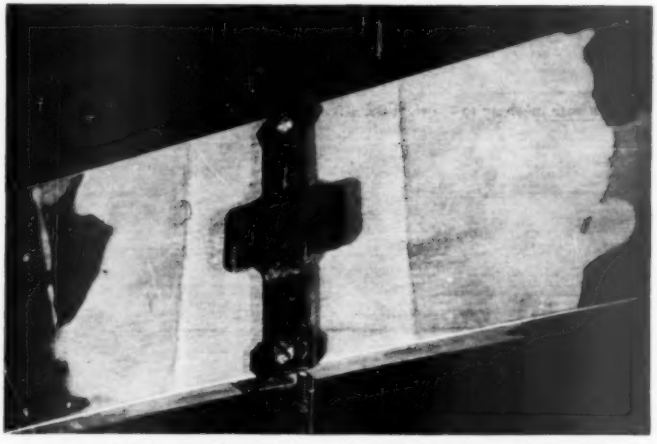

Fig. 6 Aluminum alloy specimen with center yokes

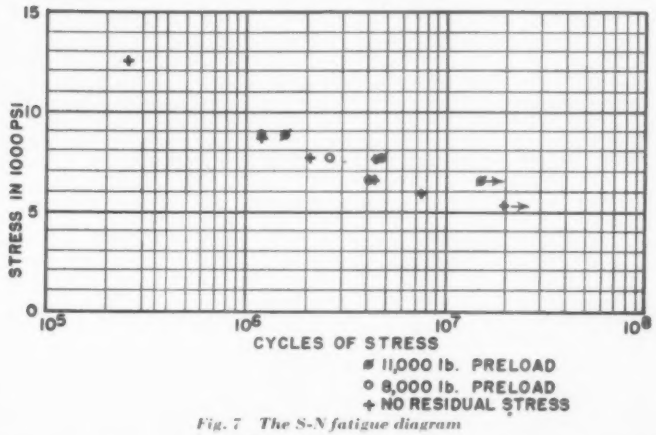

Fig. 7 The S-N fatigue diagram

able change in the fatigue behavior of the aluminum alloy under review. Figure 8 shows the degree of damage at failure in various specimens. It is seen that the damage is about the same regardless of number of cycles or condition of prestressing, thus justifying the criterion of failure which has been adopted.

B. Residual Stress

The results of the fatigue tests cannot be fully intrepreted without the knowledge of the amount of residual stress set up by preloading. Figure 9 shows that the higher the preloading in tension the higher is the amount of residual compression created around the notch. However, when the specimen is cycled, the applied stress is superimposed on the residual stress, and, if the sum exceeds the value of the yield point, there is a redistribution of

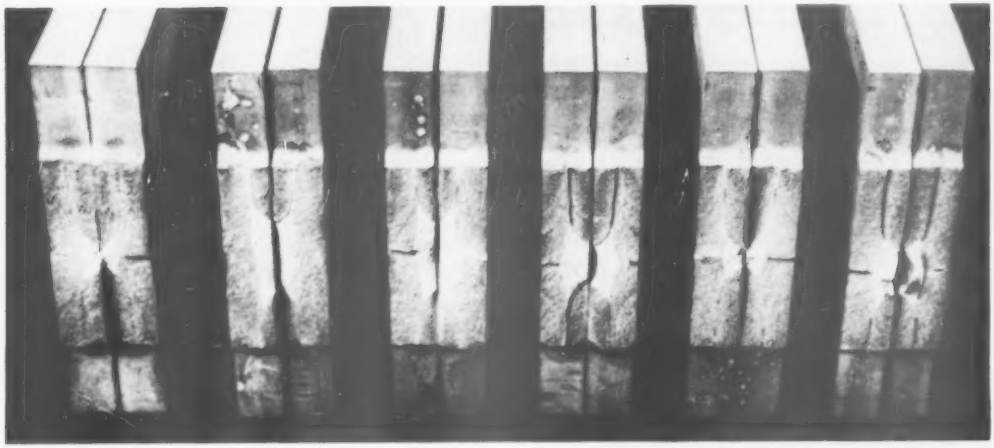

Fig. 8 Fractures of fatigue specimens

From left to right: 1. 1,099,000 cycles; stress free. 2. 1,191,000 cycles; preload, 8000 lb. 3. 2,650,000 cycles; preload, 8000 lb. 4. 4,000,000 cycles; preload, 8000 lb. 5. 4,300,000 cycles; stress free. 6. 7,410,000 cycles; stress free

This is the stress which one would obtain by dividing the bending moment by the section modulus of the notched section.

RESULTS

A. Fatigue Tests

In Fig. 7 are grouped the results of tests performed on all three series of specimens. It is seen that the points of the *S-N* curve belonging to the stress-free specimens and specimens preloaded to a value of 8000 lb. lie practically on the same line.

The points corresponding to the specimens preloaded to 11,000 lb. are displaced slightly to the right, but not enough to make a substantial difference. In other words, preloading in tension up to an average stress of 19,000 psi. in the notched section has failed to produce an appreci-

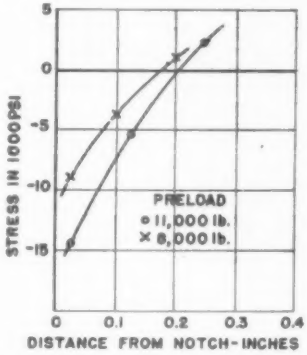

Fig. 9 Amount and distribution of residual stress caused by preloading in tension

the residual stress, as shown in Fig. 10. If the value of the yield point is known, as

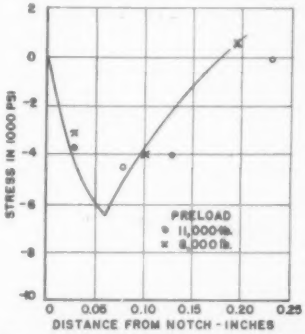

Fig. 10 Redistribution of residual stress caused by the cyclic load

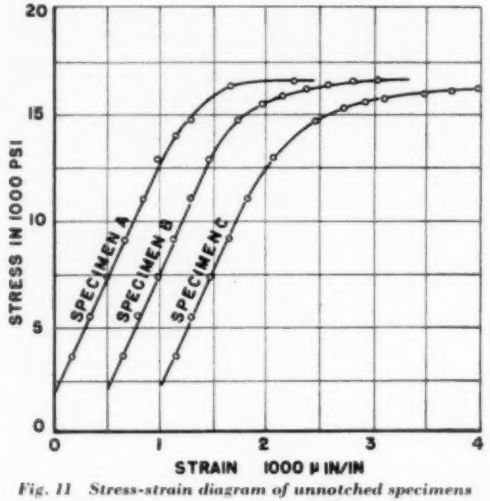

Fig. 11 Stress-strain diagram of unnotched specimens

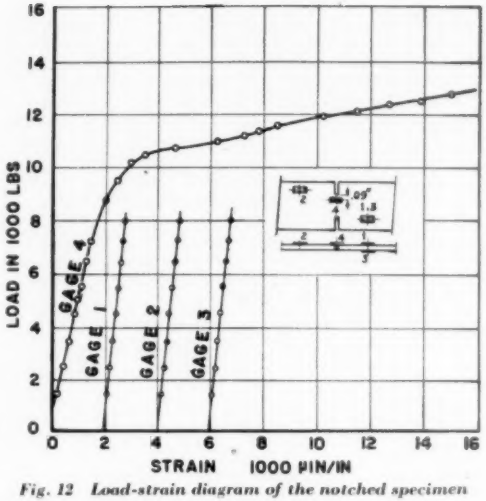

Fig. 12 Load-strain diagram of the notched specimen

well as the actual value of the cyclic stress at each point of the notched section, then the modified pattern of the residual stress can be computed approximately from the original one.[1] This computation has been carried out for the 8000-lb. preload, and a nominal applied stress of ±6500 psi. by assuming a value of yield point = 16,300 psi. The agreement between the computed and experimental values is shown in Fig. 10. Because of the greater amount of cold work and its possible influence on the yield point, the above computation fails in the case of the 11,000-lb. preload. But the experimental results are not very much different from those obtained for the 8000-lb. preload. In both cases, the residual stress pattern has been reduced after cycling to a compression barrier of about 4000 psi. located approximately 0.1 in. away from the notch. This pattern was obtained after a few thousand cycles, but it was found to undergo no significant change even after one million cycles.

C. *Tensile Tests*

To complete the picture, the results of tensile tests will be reported briefly. As seen from Fig. 11, the unnotched specimens exhibit a well-defined yield point which is missing in the notched specimen, Fig. 12. The amount of plastic deformation near the notch recorded for the two values of preload, namely, 8000 and 11,000 lb., is well below 1%, although in the latter case the whole notched section has been taken above the yield point.

DISCUSSION OF THE RESULTS

When the results of this present fatigue investigation are compared with those reported previously for mild steel,[1] it is found that the preloading which was beneficial to mild steel had no effect on the stress-relieved aluminum alloy, 61S. In an attempt to explain this discrepancy, two possibilities were examined: (*a*) The amount of residual stress was not large enough and (*b*) the beneficial effect of residual stress was offset by some antagonistic factor, e.g., by cold work.

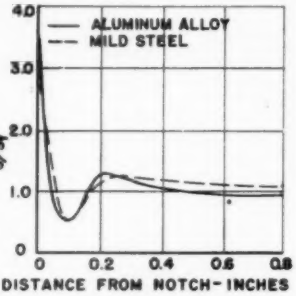

Fig. 13 Stress distribution at the peak of the tension cycle in prestressed 61S and mild steel fatigue specimens

In order to examine the validity of the first assumption the stresses existing in the notched section at the tension peak of the fatigue cycle in the prestressed aluminum alloy 61S and mild steel specimens were plotted on the same diagram, Fig. 13. To make the comparison possible, the stresses were plotted not in their absolute value, but as multiples of the fatigue stress of the stress-free specimens at 10^7 cycles. From this comparison it appears that the relative amount of residual stress is about the same in both cases. Thus, the assumption that the residual stresses were not large enough is not tenable.

Neither can the effect of cold working offer a plausible explanation. For one thing, the amount of plastic deformation recorded during preloading was not large enough to account for such an effect. For another, even though the local deformation at the notch might have been a great deal larger than the one which was actually recorded over $^1/_4$ in., still the results in fatigue were, if anything, slightly better for the higher than for the lower preload. This circumstance precludes any *adverse* effect of the preloading.

CONCLUSION

From the foregoing discussion it must be inferred that the nature of the materials employed is the only factor that can account for the reported difference in the fatigue behavior. It will be recalled that in the case of notched mild steel the compression barrier set up by preloading in tension has caused the incipient fatigue crack to propagate at a much slower rate. The inference is that in the aluminum alloy the compression barrier has less effect on the rate of crack propagation than in steel. Since the aluminum alloy was not tested in its usable condition, a more extensive research is necessary to ascertain whether the observed phenomenon is common to all aluminum alloys, or whether it is caused by the stress-relief treatment of the 61S aluminum alloy.

ACKNOWLEDGMENTS

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Appendix

CALIBRATION OF THE AMPLITUDE OF VIBRATION FOR THE STRESS IN THE NOTCHED ALUMINUM SPECIMEN

It was necessary to determine experimentally the stress that resulted when the specimen had a certain amplitude of vibration, because the nonuniformity of the cross section at the notch and the nonuniform weight distribution caused by the steel shoes added to the ends and center of the specimen made the mathematical analysis not amenable.

A $^1/_4$-in. SR-4 electric strain gage was fastened at the center of each side of the specimen. Electric connection to the strain gages was made by No. 30 enameled wire led along the upper surface of the specimen and was brought off at the node.

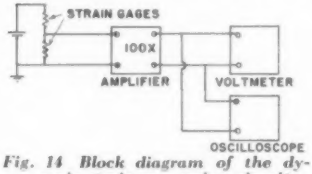

Fig. 14 Block diagram of the dynamic strain measuring circuit

The strain gages are shown in Fig. 14 connected in series across a d.-c. voltage provided by four dry cells. The total resistance of the two gages remains constant, because the gages are on opposite sides of the specimen, so when one gage contracts the other elongates and the changes in resistance are equal and opposite. Since the total resistance remains constant there is a constant value of direct current flowing through the gages at all times. A small voltage is generated across the individual gage because a constant direct current is flowing through it and its resistance alternates a small amount each vibration. This alternating voltage is amplified 100 times by the decade amplifier and the amplified signal measured by a vacuum tube voltmeter. The shape of the amplified signal was examined by an oscilloscope in parallel with the meter.

The strain gages had a gage factor of 1.97. Since the gage factor is defined as the ratio of the change in resistance per total resistance to the elastic strain, a strain of 1 micro-in./in. would cause a change in resistance of one gage of

$$1 \times 10^{-6} \times 1.97 \times 120 = 237 \times 10^{-6} \text{ ohms.}$$

The applied voltage across the two gages by the batteries was 6.48 v. causing a steady direct current to flow through the gages whose combined resistance is 240 ohms. By application of Ohms Law the current may be found:

$$I = 6.48/240 = 0.0270 \text{ amp.}$$

In the previous calculation it was found that when the gages were strained 1 micro-in./in. the resistance change for one gage was 237×10^{-6} ohms. The change in voltage is equal to the current multiplied by the change in resistance.

$$V = I \times R = 0.027 \times 237 \times 10^{-6} = 6.4 \times 10^{-6} \text{ v.}$$

Thus a voltage of 6.4×10^{-6} v. results when the strain is 1 micro-in./in., and after an amplification of 100 times the voltage applied to the vacuum tube voltmeter is 6.4×10^{-4} v. Since the alternating current voltmeter reads the root-mean-square voltage and not the peak, it will indicate $0.707 \times 6.4 \times 10^{-4}$ v.

Considerable care had to be taken in shielding the leads joining the various components of the circuit because the large amount of magnetic flux generated by the driving coils of the testing machine inducts objectionable voltages in the wires.

A series of tests was run with the amplitude of the specimen in the range from 0.025 to 0.060 in. and the output voltage recorded. These data are plotted on Fig. 15 and it is evident that the curve can be extrapolated so that it passes through the origin, indicating that there was no stray pickup or noise in the system. From the curve the voltage output for an amplitude of 0.060 is 0.300 v. (rms.) or a peak voltage of $0.300/0.707 = 0.424$ v.

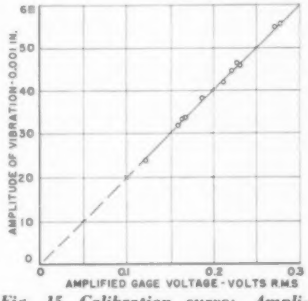

Fig. 15 Calibration curve: Amplitude of vibration vs. unbalanced voltage

It has been shown above that a strain of 1 micro-in./in. would cause a peak voltage of 6.4×10^{-4} v., therefore, for an amplitude of 0.060 in. the strain at the center of the specimen is $0.424/6.4 \times 10^{-4} = 663$ micro-in./in. Every 0.001 in. of amplitude indicates a strain of $663/60 = 11.05$ micro-in./in.

The stress on the external fibers at the center of the specimen is calculated by applying Hooke's Law, using a modulus of elasticity of 10×10^6 for aluminum, we have a stress of $663 \times 10^{-6} \times 10 \times 10^6 = 6630$ psi. for an amplitude of 0.060 in.

This is the stress at the center, not the average stress. In a previous investigation* it was shown that the stress at the center is 85% of the average stress. The average stress is $6630/0.85 = 7150$ psi.

It was necessary to make a check calibration of the instrumentation because it was possible that the amplification might not be exactly 100 times, the output meter might not be accurate or there could be attenuation in the leads. The following method was used to perform this calibration. The leads were disconnected from the gage circuit and placed across a known source of voltage at the same frequency as fatigue testing frequency (186 cps.). The standard source of voltage was provided by a voltage divider across the output of an audio oscillator. The voltage divider consisted of two precision decade boxes. The top box was set at 10,000 ohms and the lower one at 3 ohms so that the voltage applied to the gage measuring circuit was 3/10,000 of the voltage output of the audio oscillator. The voltage of the oscillator was measured by a Ballantine electronic voltmeter, calibrated by a precision Polymaster voltmeter.

A series of readings was taken at various applied voltages and the gage circuit output meter readings were taken.

This calibration showed a deviation of less than 0.6%

The accuracy of the gage factor is given by the manufacturer to be plus or minus 1%. The modulus of elasticity is known to within 1% so the determination of the stress at the center of the notched specimen should be within 3% of the actual value.

* See Ref. 1.

Corrosion Resistance of Powder-Cut Stainless Steels

The heat-affected zone of powder-cut edges may be eliminated by using stabilized or extra-low-carbon stainless steels or by annealing the powder-cut unstabilized stainless steels. The zone may be minimized by water-quenching simultaneously with the cutting.

by L. E. Stark and C. R. Bishop

INTRODUCTION

USE of the powder process for cutting stainless steels has grown to considerable importance. Among its many uses are the removal of gates and risers from castings and hot tops from ingots, and the cutting of slabs to suitable lengths for further rolling. For these uses, little concern need be given to the effect of the cutting on the properties of the materials other than that the slight amount of oxide that is retained on the surface may have to be removed. With more widespread application to rolled materials, however, particularly in the chemical equipment field, questions have arisen regarding the effects of the process on the corrosion resistance of the steels, especially in cases when the fabricated equipment cannot be annealed after cutting. The method is well suited to the beveling of plates in preparation for welding, but here also the question has arisen as to what extent the powder-cutting operation has affected the metal, and whether the heat effects of the cutting and welding operations are additive. Other important points of interest are how the effect varies with different types of stainless steels, how much material must be removed from the cut surface in order to restore the original corrosion resistance, and whether the heat effect can be corrected by suitable annealing or minimized by modifications in the cutting procedure.

It is well known that treatment of the unstabilized chromium-nickel stainless steels, within the temperature range of about 500 to 800° C., causes carbide precipitation to occur at the grain boundaries with resultant deleterious effects on the corrosion resistance in some media. This effect is produced when the metal is heated within the sensitizing range, regardless of the method used in applying the heat, whether it be by welding, uniformly heating in a furnace, or powder-cutting. The intensity of the heat effect is dependent upon time and temperature. If the entire specimen is held in the temperature range for a sufficient length of time, it is affected throughout its entire body. If, however, only a narrow band of the metal is brought to the sensitizing temperature range as in welding and cutting, then the affected areas will be confined to that narrow zone. A temperature gradient, of course, cannot be avoided if welding is to be used or if the powder process is to be used for cutting the plate. However, it has been shown that time at the sensitizing temperature is a very important factor in determining the amount of chromium carbide that will precipitate at the grain boundaries. Therefore, if a water quench, applied simultaneously with the powder-cutting operation, would materially reduce the time during which the narrow heat-affected band of the plate remains in the sensitizing temperature range, it should be possible to reduce the extent and lessen the degree of carbide precipitation in the heat-affected zone, and thus attain improved corrosion resistance at the cut edge.

Columbium-bearing stainless steel (Type 347) is not subject to the ill effects produced in ordinary 18-8 chromium-nickel steels by heat, such as that encountered in cutting and welding, and for this reason the steel has wide application for corrosion-resistant equipment requiring welding or stress-relieving.

HEAT EFFECTS FROM POWDER-CUTTING AND WELDING

Four types of austenitic steels were selected for use in the tests because of their wide application in the

Table 1—Chemical Analyses of Steels Used for Powder-Cutting and Welding Tests

Type steel	*% C*	*% Cr*	*% Ni*	*% Cb*	*% Mo*
304	0.076	18.20	8.24	..	..
310	0.086	24.70	19.98	..	..
316	0.078	17.74	13.50	..	2.26
347	0.072	18.50	11.00	0.56	..

L. E. Stark and **C. R. Bishop** are connected with the Union Carbide and Carbon Research Laboratories Inc., Niagara Falls, N. Y.
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corrosion-resisting field.* The types and analyses of the steels are listed in Table 1.

The plates, which were 1/2 in. thick by 12 in. long by 6 in. wide, were beveled to 30° by the powder-cutting method under commercial conditions, in preparation for welding by both the submerged melt and the manual arc processes. Plates for the submerged melt welds had a 3/16-in. nose, while those for the manual arc welds had a 1/16-in. nose. The powder-cutting conditions used in beveling the plates are shown in Table 2. In addition to the plates beveled in the normal manner, several specimens were prepared by cutting at an abnormally slow speed. These specimens in the as-cut and annealed conditions were included in the tests for comparative purposes. The conditions under which the abnormal cuts were made are shown in Table 2A.

Both submerged melt and manual arc welds were made in steel plates of the four types, the beveled edges of which were prepared by powder-cutting, by powder-cutting followed by sandblasting, by powder-cutting followed by grinding until visible oxide was removed and by machining using no powder-cutting. The welding conditions for these welds are given in Table 3.

The results of X-ray tests indicate that the method of edge preparation had little effect on the soundness of the welds. It was observed that during manual arc welding, the slag produced on the first pass by welding on the powder-cut edges was harder to remove than that from welds made on ground or machined surfaces. However, this condition seemed to be of little consequence since only the first bead was affected in this manner. Therefore it would seem advisable, wherever possible, to remove the thin layer of oxide from the cut face before welding as this can be done readily by moderate grinding or sandblasting.

Table 2

Powder-Cutting Conditions Used for Beveling 1/2-In. Thick Plates of Stainless Steels

Oxygen pressure at blowpipe, psi	50
Cutting tip orifice diameter, in.	0.0995
Length of preheat flame, in. (adjusted to neutral flame)	3/16
Powder consumption, oz. per minute	4
Conveying air flow, cu. ft. per hour	48
Speed of cutting, in. per minute	20

Table 2A

Powder-Cutting Conditions Used for Beveling 1/2-In. Thick Plates of Stainless Steels at Abnormally Slow Cutting Speeds

Oxygen pressure at blowpipe, psi	50
Cutting tip orifice diameter, in.	0.0995
Length of preheat flame, in. (adjusted to neutral flame)	5/16
Powder consumption, oz. per minute	4
Conveying air flow, cu. ft. per hour	48
Speed of cutting, in. per minute	12

NOTE: Two successive cuts were made on the edges, as close together as possible in order to *exaggerate* the heat-affected zone.

Table 3

Conditions Used in Making the Manual Arc Welds in 1/2-In. Thick Plates of Stainless Steel Beveled by Powder-Cutting or Machining

Type of Steel	*Type of Electrode*
304 (18–8)	304 (19–9)
310 (25–20)	310 (25–20)
316 (18–8 Mo)	316 (18–12 Mo)
347 (18–8 Cb)	349 (19–9 Cb)

NOTE: The following conditions were constant for all manual welds: 3/16-in. diam. coated electrodes; d.-c. reverse polarity—150 amp., 26 v. (max.)—short arc; 6 passes—work cooled to 212° F. after each pass; copper backing used.

Conditions Used in Making the Submerged Melt Welds in 1/2-In. Thick Plates of Stainless Steel Beveled by Powder-Cutting or Machining

Type of Steel	*Type of Electrode*
304 (18–8)	304 (18–8)*
310 (25–20)	310 (25–20)
316 (18–8 Mo)	316 (18–8 Mo)
347 (18–8 Cb)	347 (18–8 Cb)

NOTE: The following conditions were constant for all submerged melt welds: 1/4-in. diam. bare electrodes; Unionmelt 80-grade, 20 by D; d.-c. reverse polarity—840 amp., 34–35 v.; 18 in. per minute.

* Except Weld No. 20U which was welded with Type 347 (18–8 Cb) steel electrode.

Metallographic examinations were carried out on Type 304 and Type 347 steels, since they seemed to represent about the worst and best conditions from among the steels most generally encountered in welding practice. The examination of the powder-cut surfaces from which only the loose scale had been flaked off showed that there was a very thin adherent coating of oxide and melted metal present on the surfaces of the steels. Figures 1, 5, 7 and 11, at 100 ×, show that these areas were less than 1/64 in. thick. Since this layer is not stain- or rust-resisting, due to the presence of oxides and embedded iron particles, it should be removed if this type of resistance in the powder-cut part is needed. This thin layer of oxide and melted metal can be completely removed by grinding or machining approximately 1/64 in. from the surface. Experience has shown that whenever the cut surface was ground to a metallic clean appearance, this layer of affected metal had been completely removed.

It was observed that Type 304 steel had heat-affected zones where carbide precipitation had occurred at the grain boundaries near the powder-cut edges and the welds. The effect from powder-cutting was the same in character as that produced by welding, but less severe. On the other hand, the Type 347 steel (18–8 columbium) did not show any carbide precipitation after either of these operations. Figures 2 and 4 show the areas of carbide precipitation in the Type 304 steel, and Figs. 8 and 10 show the lack of carbide precipitation in corresponding areas of Type 347 steel. Heat-treatment of the Type 304 steel at 1075° C. for 20 min., followed by air-

* NOTE: Type 304 (18–8). General purpose corrosion-resistant alloy. Common welding alloy. Susceptible to carbide precipitation and intergranular corrosion.

Type 310 (25–20). High resistance to heat oxidation and chemical corrosion. Increased resistance to carbide precipitation and intergranular corrosion.

Type 316 (18–8 Mo). Increased resistance to specific corrosive agents. Susceptible to carbide precipitation and intergranular corrosion.

Type 347 (18–8 Cb). Stabilized to prevent carbide precipitation and intergranular corrosion.

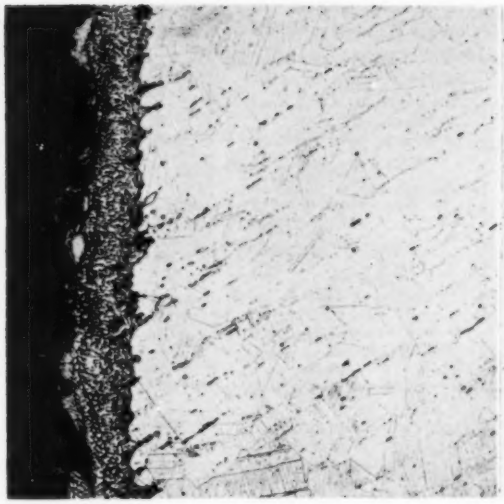


Fig. 1 Type 304 steel, powder-cut edge. Layer of oxide and melted metal less than 0.01 in. thick at left. × 100

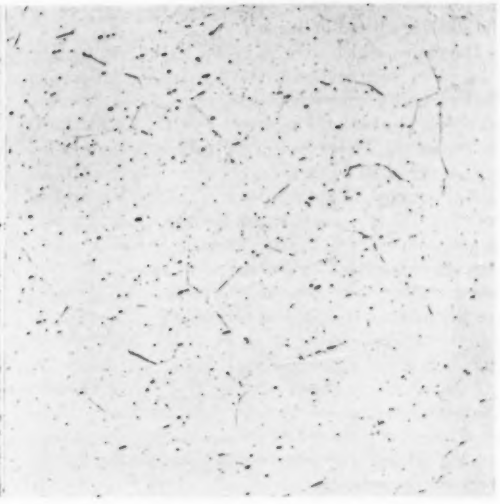


Fig. 2 Same sample as Fig. 1 at about 1/8 in. from powder-cut edge in heat-affected zone. Note carbide precipitation at grain boundaries. × 100

cooling, completely removed the precipitate that had occurred at the grain boundaries. The same heat-treatment apparently did not change the microstructure of the Type 347 steel since there was no carbide precipitation originally. Figures 6 and 12 are photomicrographs of the two steels in the heat-treated condition.

Specimens of powder-cut and welded plates of the four types of steels were subjected to the action of a solution containing 3% hydrofluoric acid and 10% nitric acid at a temperature of 77° C. for five 1-hr. periods, fresh solution being used for each period. This solution was selected because it was able to attack, within a short time, any areas low in corrosion resistance as the result of carbide precipitation or dilution of the metal (reference is made to the value of this solution for this purpose in the *Welding Handbook*, p. 807, 1942). The solution also serves as an excellent pickle for stainless steels, and it readily removes the scale from the cut surface.

Fig. 3 Type 304 steel, submerged melt weld made on powder-cut beveled edges. As-welded; portion of weld metal at left. × 100

Fig. 4 Same sample as Fig. 3 at about 1/8 in. from weld in heat-affected zone. Note carbide precipitation at grain boundaries. The banded appearance is due to the presence of ferrite and inclusions. × 100

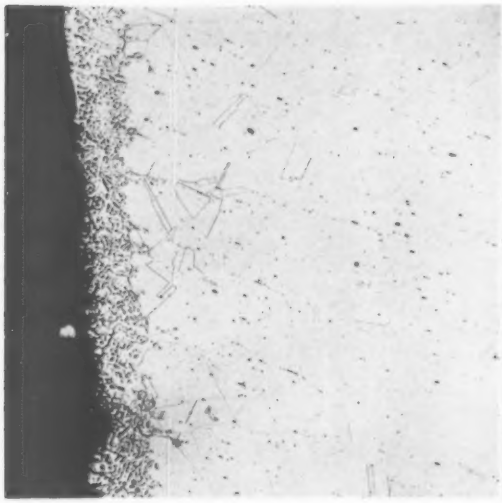


Fig. 5 Type 304 steel, cut edge at left. Specimen heat-treated after powder-cutting. × 100

Fig. 6 Same sample as Fig. 5 at about 1/8 in. from powder-cut edge. Note lack of carbide precipitation at the grain boundaries after heat-treatment. × 100

While the Type 304 steel was readily attacked at the heat-affected zones by the hydrofluoric-nitric acid solution, the Type 310 and Type 316 steels required a longer time to show any appreciable attack at these areas, and the Type 347 steel was free from any areas of increased attack. The conditions of the specimens after the tests are shown in Figs. 13 to 18, inclusive, and the following points are clearly brought out by the photographs.

1. The specimens of Type 347 steel were entirely free from any areas of increased corrosion, regardless of whether the specimens were powder-cut in a fast or slow manner, or had been annealed after powder-cutting, or had been subsequently welded by manual arc, or submerged melt methods.

2. The Type 304, Type 310 and Type 316 steels showed zones of increased attack near the welded and the powder-cut areas. Although the zones were not so prominent on the Type 310 and Type 316 steels as on the Type 304 steel, they were sufficiently deep to indicate areas of definitely lowered corrosion resistance.

3. Powder-cutting in the normal manner produced heat-affected areas on the unstabilized steels that were

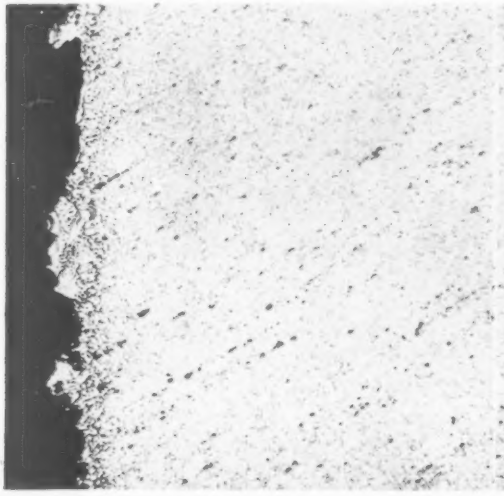


Fig. 7 Type 347 steel, powder-cut edge. Layer of melted metal less than 0.01 in. thick at left. × 100

Fig. 8 Same sample as Fig. 7 at about 1/8 in. from powder-cut edge. Note lack of carbide precipitation in the powder-cut Type 347 steel. × 100

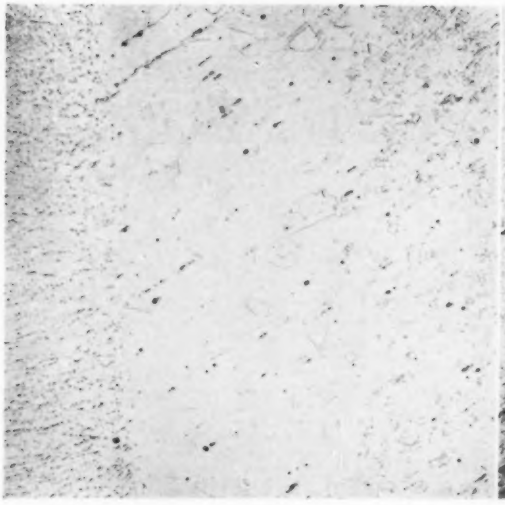


Fig. 9 Type 347 steel, submerged melt weld made on powder-cut beveled edges. As-welded; portion of weld at left. × 100

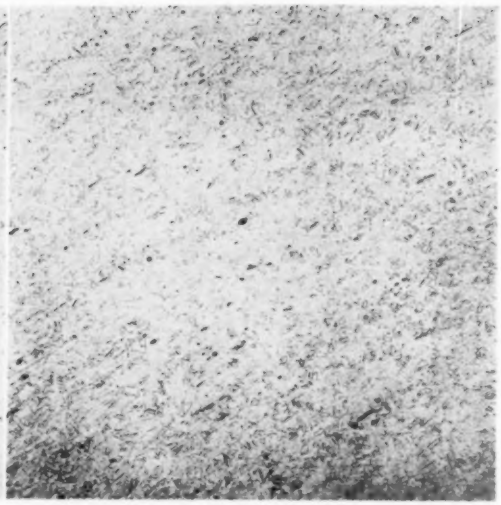


Fig. 10 Same sample as Fig. 9 at about 1/8 in. from weld. Note lack of carbide precipitation in as-welded Type 347 steel. × 100

narrower than those produced by either manual arc or submerged melt welding, but the use of slow cutting speeds or repetitive cutting resulted in heat-affected areas comparable to those produced by welding.

4. Welds made in plates beveled by powder-cutting were no different in respect to the extent of the heat-affected areas from those made in plates beveled by machining, thus showing that the heat effect from the powder-cutting was not added to that produced by the welding. In fact, indications were that the metal in the narrow heat-affected areas adjacent to the cut edge was actually melted during the welding. This was especially true in the case of the submerged melt welds.

5. The heat-affected areas caused by the powder-cutting on the Type 304, Type 310 and Type 316 steels were entirely eliminated by proper heat-treating after cutting. Likewise, the Type 304 steel which had been powder-cut and welded was restored to full corrosion resistance by proper heat treatment.

6. Figure 18 shows the powder-cut surfaces of specimens that were placed in test in the hydrofluoric-nitric acid solution without first removing the scale from the

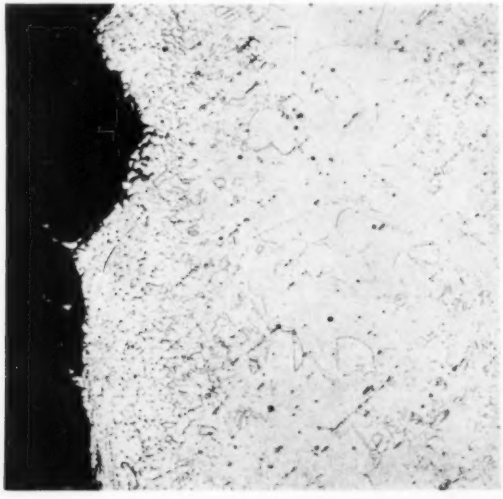


Fig. 11 Type 347 steel, heat-treated after powder-cutting. Layer of melted metal less than 0.01 in. thick at left. × 100

Fig. 12 Same sample as Fig. 11 at about 1/8 in. from powder-cut edge. Note similarity of structure with that of powder-cut and as-welded specimens (Figs. 8 and 10). × 100

powder-cut faces. Some of the specimens had been heat-treated after powder-cutting. Indications were that after the acid had removed the surface scale, the powder-cut faces were as resistant as the original annealed body of the samples, showing that these faces were not appreciably diluted by the cutting operation. It was further shown that there was no noticeable difference in attack on the powder-cut faces of the samples in the as-cut and heat-treated conditions.

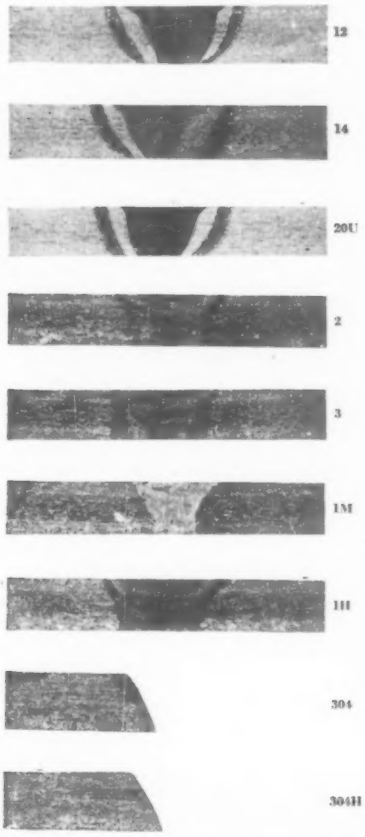


Fig. 13 Powder-cut and welded specimens of Type 304 steel after corrosion test in a solution containing 3% hydrofluoric acid and 10% nitric acid, 77° C., five 1-hr. periods. Edge views of specimens

Spec. No.	*Type of steel*	*Edge preparation before welding*	*Kind of weld*
12	304	Powder-cut	Submerged melt
14	304	Powder-cut and ground	Submerged melt
20U	304	Machined	Submerged melt
2	304	Powder-cut	Manual arc
3	304	Powder-cut and ground	Manual arc
1M	304	Machined	Manual arc
1H	304	Powder-cut and sandblasted	Manual arc; heat treated, 1075° C., 20 min., a. c.
304	304	Powder-cut	None
304H	304	Powder-cut, heat treated, 1075° C., 20 min., a. c.	None

Note the increased attack at the heat-affected areas near the welds and powder-cut edges on the non-heat-treated samples.

MINIMIZING THE HEAT EFFECTS OF POWDER-CUTTING

Since time at the sensitizing temperature range is an important factor in determining the amount of chromium carbide that will precipitate at the grain boundary, a series of experiments was carried out in which a water quench was applied simultaneously with the powder-cutting operation. Type 302 and Type 304 steels were used in these tests. The analyses of these steels are listed in Table 4.

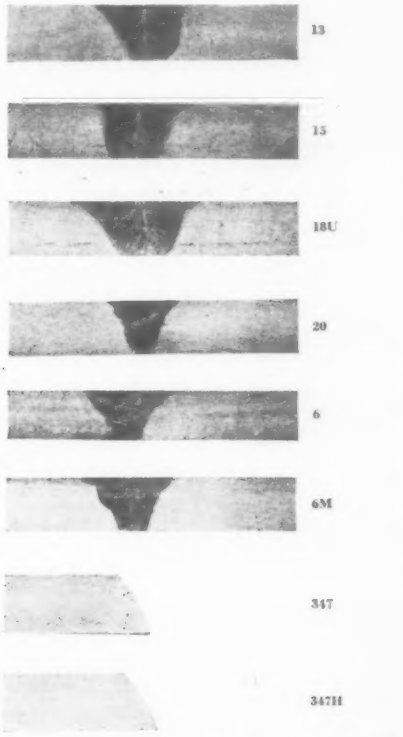


Fig. 14 Powder-cut and welded specimens of Type 347 steel after corrosion test in a solution containing 3% hydrofluoric acid and 10% nitric acid, 77° C., five 1-hr. periods. Edge views of specimens

Spec. No.	*Type of steel*	*Edge preparation before welding*	*Kind of weld*
13	347	Powder-cut	Submerged melt
15	347	Powder-cut and ground	Submerged melt
18U	347	Machined	Submerged melt
20	347	Powder-cut	Manual arc
6	347	Powder-cut and ground	Manual arc
6M	347	Machined	Manual arc
347	347	Powder-cut	None
347H	347	Powder-cut and heat treated, 1075° C., 20 min., a. c.	None

Note the absence of increased attack on all specimens.

Cutting with the plate completely immersed in water was first attempted, but splashing caused interference with the powder flow, and the blast of the cutting gases kept the water away from the cutting zone with the result that the cut edge was not quenched satisfactorily.

The early tests with quenching apparatus also showed that quenching from the top only, gave insufficient cooling to maintain the corrosion resistance of the entire edge with the result that the underside of the plate developed a heat-affected zone. This condition necessi-

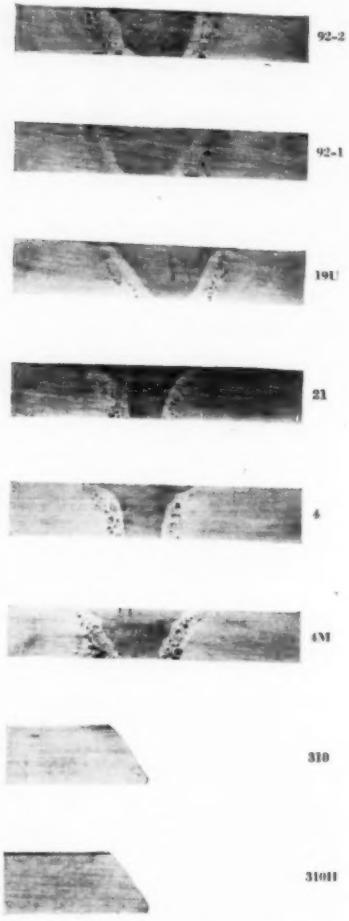


Fig. 15 Powder-cut and welded specimens of Type 310 steel after corrosion test in a solution containing 3% hydrofluoric acid and 10% nitric acid, 77° C., five 1-hr. periods. Edge views of specimens

Spec. No.	Type of steel	Edge preparation before welding	Kind of weld
92-2	310	Powder-cut	Submerged melt
92-1	310	Powder-cut and ground	Submerged melt
19U	310	Machined	Submerged melt
21	310	Powder-cut	Manual arc
4	310	Powder-cut and ground	Manual arc
4M	310	Machined	Manual arc
310	310	Powder-cut	None
310H	310	Powder-cut and heat treated, 1150° C., 20 min., a. c.	None

NOTE: With the exception of the heat-treated specimen 310H, all of the specimens showed increased attack near the welds or powder-cut edges.

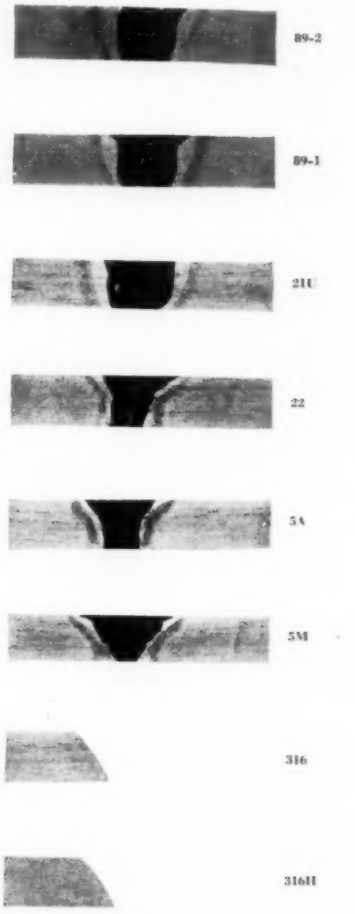


Fig. 16 Powder-cut and welded specimens of Type 316 steel after corrosion test in a solution containing 3% hydrofluoric acid and 10% nitric acid, 77° C., five 1-hr. periods. Edge views of specimens

Spec. No.	Type of steel	Edge preparation before welding	Kind of weld
89-2	316	Powder-cut	Submerged melt
89-1	316	Powder-cut and ground	Submerged melt
21U	316	Machined	Submerged melt
22	316	Powder-cut	Manual arc
5A	316	Powder-cut and ground	Manual arc
5M	316	Machined	Manual arc
316	316	Powder-cut	None
316H	316	Powder-cut and heat treated, 1125° C., 20 min., a. c.	None

NOTE: With the exception of the heat-treated specimen 316H, all of the specimens show increased attack near the weld or powder-cut edge.

tated the application of water to the underside of the plate during cutting.

The water-quenching equipment developed was for experimental purposes and probably would not be satisfactory for commercial use. However, fabrication of supplementary water-quenching equipment for minimizing the heat effect should be such that the quenching water at the top of the cut will thoroughly wet the top surface on each side of the cut and both walls of the kerf. The quenching equipment for the bottom of the plate will, undoubtedly, require individual fabrication depending on the shape being cut and the width of the material. In all cases, the water quench, to be effective, must be applied as close behind the cutting flames as possible. If the water stream is supplied at a moderate

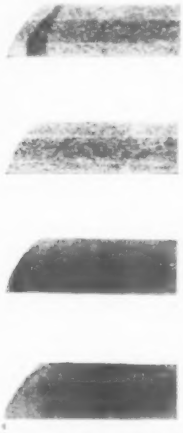


Fig. 17 Specimens of Type 304 and Type 347 steels cut twice at abnormally slow speed to exaggerate the heat effect. Tested in a solution containing 3% hydrofluoric acid and 10% nitric acid, 77° C., five 1-hr. periods

Spec. No.	Type of steel	Edge preparation
304X	304	Powder-cut
304XH	304	Powder-cut and annealed, 1075° C., 20 min., a. c.
347X	347	Powder-cut
347XH	347	Powder-cut and annealed, 1075° C., 20 min., a. c.

Note that the powder-cut specimen 304X of Type 304 steel shows a wide zone of increased attack at the heat-affected area near the cut edge, and that the annealed specimen 304XH does not show any heat-affected zone. The Type 347 steel does not show any heat-affected areas in either the powder-cut or annealed specimens.

Table 4—Chemical Analyses of Steels Used for Normal and for Water-Quenched Powder-Cutting Tests

Type of steel	Thickness, in.	% C	% Cr	% Ni	% N
302	1/4, 1/2, 3/4, 1	0.11	18.29	9.10	0.055
304	1/4	0.069	18.82	9.29	0.031
304	1/2	0.076	18.20	8.24	0.029
304	3/4	0.077	19.40	9.23	0.047
304	1	0.070	19.80	9.38	0.046
304 L. C.	1/4, 1/2, 3/4, 1	0.035	18.28	9.58	0.022

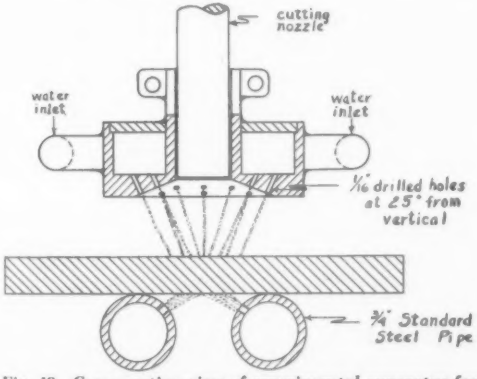


Fig. 19 Cross-section view of experimental apparatus for quenching the top and bottom of plates during powder-cutting

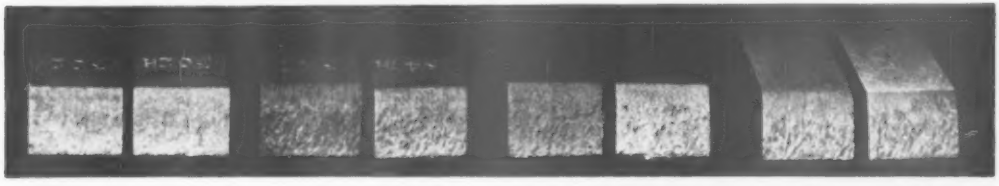


Fig. 18 Powder-cut beveled edges of specimens after test in a solution containing 3% hydrofluoric acid and 10% nitric acid, 77° C., five 1-hr. periods

Spec. No.	Type of steel	Edge preparation
304	304	Powder-cut
304H	304	Annealed after powder-cutting
347	347	Powder-cut
347H	347	Annealed after powder-cutting
310	310	Powder-cut
310H	310	Annealed after powder-cutting
316	316	Powder-cut
316H	316	Annealed after powder-cutting

Note that none of the powder-cut faces shows any signs of excessive attack and that the faces of the powder-cut samples appear to be as resistant as those of the heat-treated specimens.

All specimens placed in test with scale retained on cut face.

Table 5—Conditions Used for Normal and Water-Quenched Powder-Cutting of Stainless Steel Plates of Various Thicknesses

Type of steel	*Thickness, in.*	*Type of cut*	*Cutting tip orifice, diam., in.*	*O_2 pressure at blowpipe, psi.*	*Powder consumption, oz./min.*	*Speed, ipm.*
302, 304, 304 L. C.	1/4	Normal	0.040	60	4	25
302, 304, 304 L. C.	1/2	Normal	0.0595	50	4	22
302, 304, 304 L. C.	3/4	Normal	0.0595	50	4	17 1/2
302, 304, 304 L. C.	1	Normal	0.0595	50	4 1/2	15
302, 304	1/4	Water-quenched	0.040	60	4	34
302, 304	1/2	Water-quenched	0.0595	50	4	22
302, 304	3/4	Water-quenched	0.0595	50	4	17
302, 304	1	Water-quenched	0.0595	50	4 1/2	15
304	1/2	Normal and water-quenched. Time-temperature recorded	0.0595	50	4	20

rate so no splashing occurs, the presence of the water will have no adverse effect on the cutting operation itself.

The supplementary experimental equipment used for applying a water quench with the powder-cutting is shown in Fig. 19. The water flow rates used in these tests were 25 gal. per hour for quenching the top of the plates and 25 gal. per hour per inch of length for quenching the bottom of the plates. The cutting conditions for each plate are given in Table 5.

In order to obtain data on the effect of this water quenching on the time-temperature conditions in the heat-affected zone adjacent to the cut edge, cuts were made in plates in which a thermocouple had been embedded, and the complete thermal history of the metal at that point during cutting was obtained. The thermocouples were embedded 1/8 in. in the plate and the line of cutting passed a measured distance from the point of contact. This distance was checked after cutting. The time-temperature data were obtained on a recording millivoltmeter and these data are shown in Fig. 20. Study of these curves obtained on 1/2-in. thick Type 304 steel during normal and water-quenched cutting tests shows that the use of a water quench materially reduced the time during which the narrow heat-affected band of the plate remained in the sensitizing temperature range and thus, undoubtedly, reduced the extent of carbide precipitation in the heat-affected zone at the cut edge. As has been shown for some steels, if the time at temperature is short enough, no deterioration in corrosion resistance will occur. The time during which the heat-affected zone remained in the sensitizing temperature range of 500 to 800° C. was on the order of 2 to 2 1/2 sec. for a water-quenched cut,

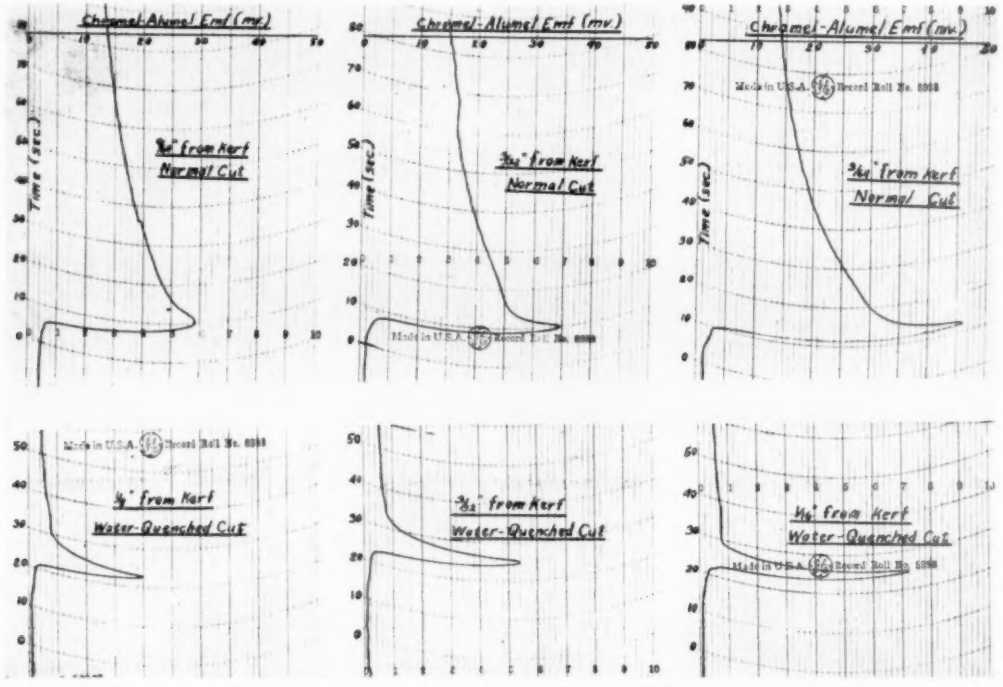


Fig. 20 Time-temperature conditions in 1/2-in. thick Type 304 steel during normal and water-quenched powder-cutting

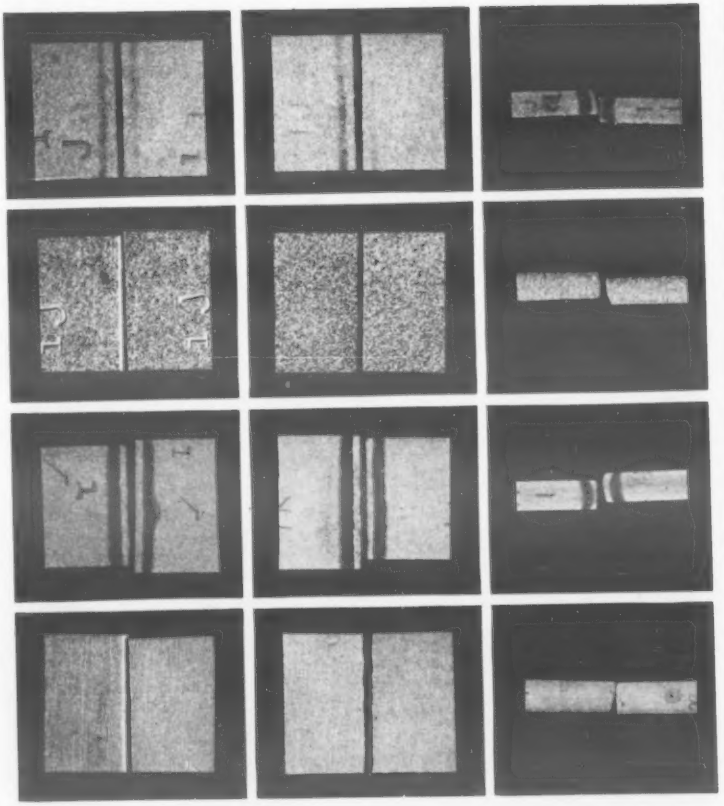


Fig. 21 Normal and water-quenched powder-cut specimens of 1/4-in. thick stainless steel after corrosion test in a solution containing 3% hydrofluoric acid and 10% nitric acid, 77° C., five 1-hr. periods. Approx. natural size. Left column shows top view, middle column bottom view and right column edge view of the same specimen

Row No.	*Type of steel*	*Type of cut*
1	302	Normal
2	302	Water-quenched
3	304	Normal
4	304	Water-quenched

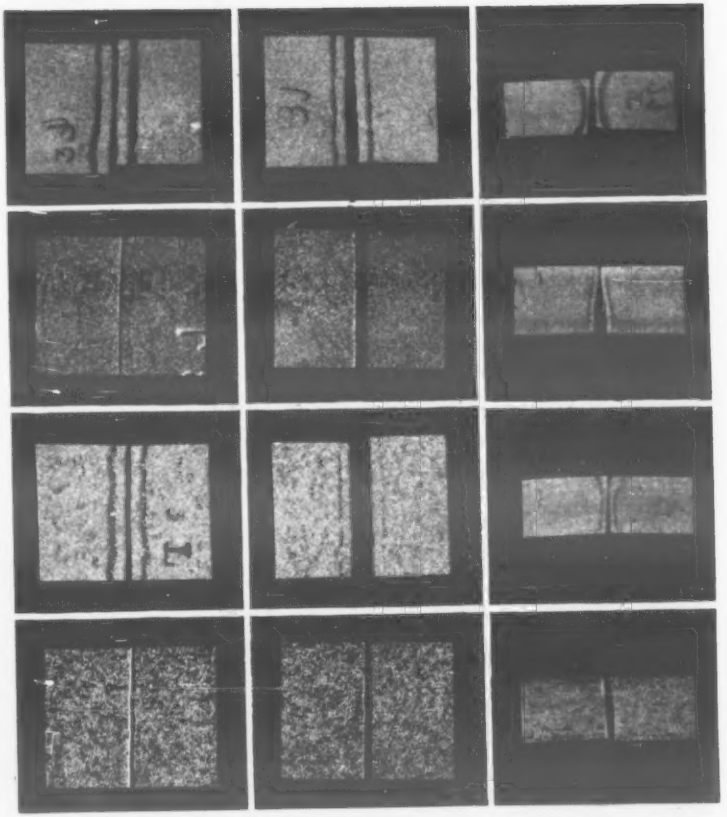


Fig. 22 Normal and water-quenched powder-cut specimens of 1/2-in. thick stainless steel after corrosion test in a solution containing 3% hydrofluoric acid and 10% nitric acid, 77° C., five 1-hr. periods. Approx. natural size. Left column shows top view, middle column bottom view and right column edge view of the same specimen

Row No.	*Type of steel*	*Type of cut*
1	302	Normal
2	302	Water-quenched
3	304	Normal
4	304	Water-quenched

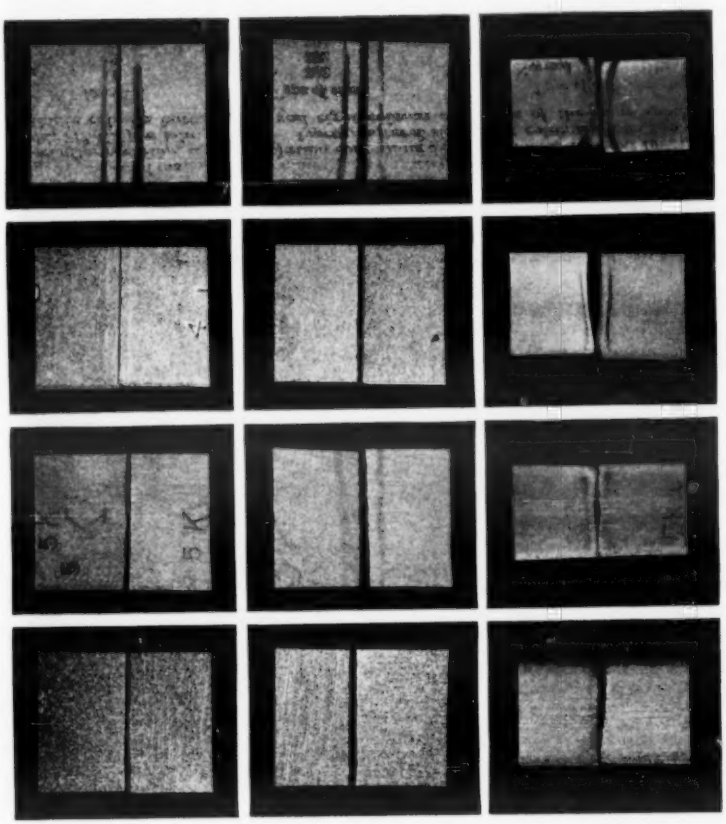


Fig. 23 Normal and water-quenched powder-cut specimens of 3/4-in. thick stainless steel after corrosion test in a solution containing 3% hydrofluoric acid and 10% nitric acid, 77° C., five 1-hr. periods. Approx. natural size. Left column shows top view, middle column bottom view and right column edge view of the same specimen

Row No.	Type of steel	Type of cut
1	302	Normal
2	302	Water-quenched
3	304	Normal
4	304	Water-quenched

Fig. 24 Normal and water-quenched powder-cut specimens of 1-in. thick stainless steel after corrosion test in a solution containing 3% hydrofluoric acid and 10% nitric acid, 77° C., five 1-hr. periods. Approx. natural size. Left column shows top view, middle column bottom view, and right column edge view of the same specimen

Row No.	Type of steel	Type of cut
1	302	Normal
2	302	Water-quenched
3	304	Normal
4	304	Water-quenched

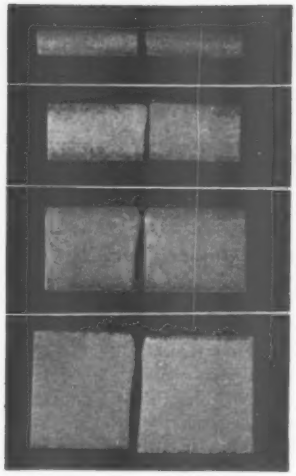


Fig. 25 Normal powder-cut specimens of Type 304 low-carbon stainless steel of 1/4-, 1/2-, 3/4- and 1-in. thickness after corrosion test in a solution containing 3% hydrofluoric acid and 10% nitric acid, 77° C., five 1-hr. periods. Edge view of specimens. Approx. natural size

whereas the corresponding time during a normal cut was on the order of 20 to 30 sec.

The effect of powder-cutting on the extent of carbide precipitation under normal and water-quenched cutting conditions was interpreted by a study of the extent of corrosion after the cut specimens had been subjected to the hydrofluoric-nitric acid corrosion test. Photographs of the corrosion-tested specimens are shown in Figs. 21 to 24. The following points are emphasized by the photographs.

1. The zone adjacent to the cut face in Type 304 steel remained corrosion-resistant in all thicknesses up to 1 in. after the water-quenched cut, but suffered loss in corrosion resistance in all normal cuts.

2. The zone adjacent to the cut in Type 302 steel showed some loss in corrosion resistance under all conditions except the 1/4-in. thick water-quenched specimen. However, the corrosion loss in all other specimens of quenched cuts was considerably less than in specimens taken from normal cuts.

3. Examination of the Type 302 water-quenched, powder-cut specimens which did not remain corrosion-resistant showed that approximately 50% less grinding or machining of the cut edge would be necessary to remove the zone of carbide precipitation because of the decreased depth of the heat-affected zone, especially near the top and bottom of the cut plate where the heat effect penetrates further back from the cut edge than it does near the center of the plate. This straightening out of the heat effect in the thicker plates is one of the valuable contributions of water quenching.

Since the carbon content of a stainless steel as well as time at the sensitizing temperature will determine the amount of chromium carbide that will precipitate at the grain boundaries, a series of normal powder cuts were made in a very low-carbon Type 304 steel of several thicknesses. The chemical analysis of this steel is given in Table 4. The cutting conditions are given in Table 5. Photographs of the corrosion-tested specimens are shown in Fig. 25. The specimens show no loss in corrosion resistance as a result of the heat effect from powder-cutting. Thus, stainless steel plate sufficiently low in carbon content, such as Type 304 ELC, may be powder-cut with no detrimental heat-effect without the use of a water-quench.

CONCLUSIONS

Powder-cut surfaces may be used directly for welding although light surface grinding or sandblasting is advisable before multipass welding.

The heat-effect from powder-cutting is not added to and is less severe than that produced by welding.

Powder-cutting produces a heat-affected zone underlying the powder-cut surface only in unstabilized steels. Full corrosion resistance is restored by a proper annealing heat treatment or by removing 3/16 in. of metal from the cut edge of plates up to 3/4 in. thick or 1/4 in. of metal from plates 1 in. thick. The corrosion resistance of stabilized stainless steels is unimpaired by powder-cutting.

The coating of adherent oxide and melted metal on the cut surface is less than 1/64 in. thick and is completely removed by grinding to a metallic clean surface.

When powder-cutting is used to form the metal and no further treatment is to be applied, the heat-effect can be minimized or eliminated by means of a supplementary water-quench accompanying the cutting or by the use of certain steels such as Type 347 (stabilized) or Type 304 ELC (extra low carbon).

Tests of Spot Welds for Light Steel Structures

Strength of arc- and spot-welded joints under repeated tensile loads

by Otto Graf

THE question arose about eight years ago as to what extent plug welds or spot welds could be used in place of riveted joints for light structures, especially with reference to repeated tensile loads. To answer this question the following tests were made in the Institute for Building Research at the Technical University of Stuttgart. Tests made on riveted joints are described in a paper published recently in *Zeitschrift Verein Deutscher Ingenieure*, Heft 10, 1948.

1. PLUG WELDS

1.1 The design of the specimens is shown in Figs. 1 to 5. The specimens in Figs. 1 and 3 contained 1 or 3 holes, 0.79 in. in diameter, in a through length of 26 or 30 in. These holes were plug welded with covered electrodes (Kjellberg St 42 C electrodes). In Figs. 2 and 4 the straps were drilled, the plug welding being done in the holes in the strap. The welds were ground smooth after welding.

The specimens of Figs. 1 to 4 were intended to show the change in strength of through plates caused by plug welds. In light structures joints of this type are used to connect cover plates to web plates. The joint in Fig. 5 is a butt joint with holes in the straps as in Figs. 2 and 4. These holes were plug welded with covered electrodes.

1.2 Results of Tensile Tests. The tensile properties of the unwelded plates used in this investigation were as follows:

Yield point, transverse to direction of rolling, psi	53,000
Yield point, parallel to direction of rolling, psi	49,000

Professor Otto Graf is located in Stuttgart, Germany.

This is a translation by G. E. Claussen of an article appearing in *Zeitschrift Verein Deutscher Ingenieure*, 1949.

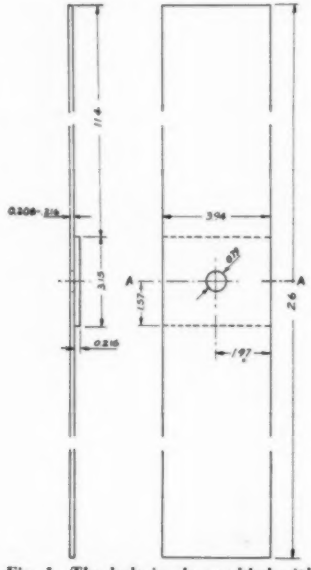


Fig. 1 The hole is plug welded with covered electrodes. The surface of the weld and its vicinity is ground. The plates have mill scale. Dimensions in inches

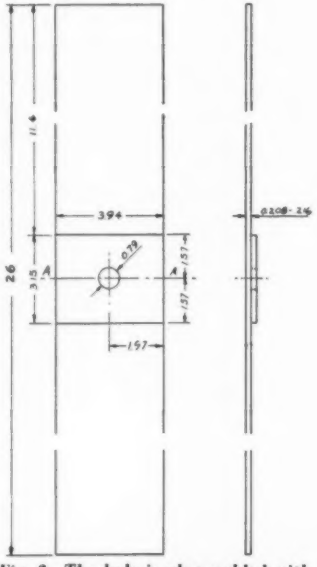


Fig. 2 The hole is plug welded with covered electrodes. The surface of the weld and its vicinity is ground smooth. The plates have mill scale Dimensions in inches

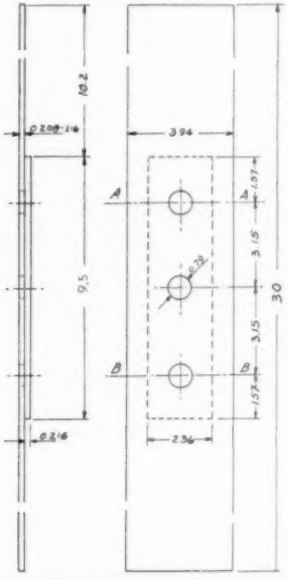


Fig. 3 Same as Fig. 1

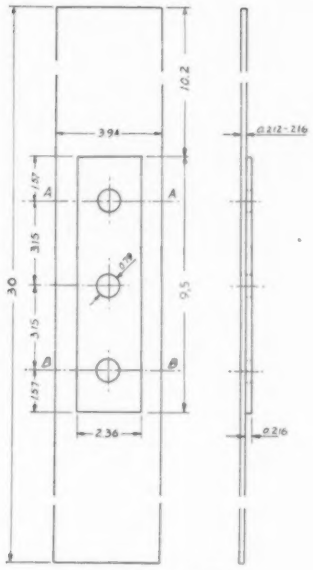


Fig. 4 Same as Fig. 2

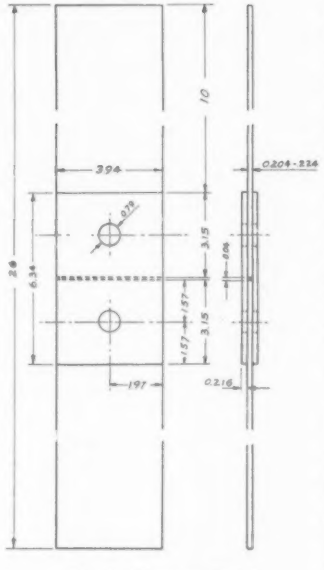


Fig. 5 Same as Fig. 2

Tensile strength, transverse to direction of rolling, psi....	68,500
Tensile strength, parallel to direction of rolling, psi.....	67,000
Elongation, transverse to direction of rolling, %.....	22.7
Elongation, parallel to direction of rolling, %.....	25.8

The tensile strength of the specimens calculated on the full cross section of the through or butted plates was 65,200 and 65,600 psi. for the specimens in Fig. 1; in Fig. 2, 65,200 and 65,900 psi.; in Fig. 3, 57,600 and 52,200 psi.; in Fig. 4, 65,200 and 65,600 psi.; and in Fig. 5, 45,100 and 45,100 psi.

The specimens in Figs. 1, 2 and 4 had about 95% of the tensile strength of the unwelded plate. The specimen in Fig. 3 had only about 80% of the tensile strength of the unwelded plates. Accordingly, it seems best to drill the holes in the straps, as shown in Figs. 2 and 4, and not in the through plate, Figs. 1 and 3. The specimens in Figs. 2 and 4 broke outside the welds at a considerable distance from Section A-A or B-B. These specimens had nearly the full tensile strength of the plates. The specimen in Fig. 1 broke at the weld; the through plate fractured. The specimens in Fig. 3 broke through the weld near Section A-A or B-B. The weld had poor root penetration. One of the specimens in Fig. 5 sheared the welds (shear strength = 39,800 psi. assuming a spot diameter of 0.79 in.). The other specimen failed in the middle plate, shearing behind a spot.

1.3 Results of Tests Using Repeated Tensile Loads. Loads were applied at the rate of 660 per minute. The lower stress, S_{su}, was 3400–4400 psi. The fatigue strength, S_{so}, is defined as the stress which will not cause fracture after one million repetitions. The fatigue strength, S_{so}, and the fatigue range, $S_{so} - S_{su}$, were calculated on the full cross section of the through or butted plates, Table 1. These results show greater strength for the specimens in Figs. 1 and 2 with straps $3^1/_8$ in. long than for Figs. 3 and 4 with straps $9^1/_2$ in. long containing three plug welds. This difference is caused by the bending strains set up near the outer

Table 1—Fatigue Strength and Range, Psi.

Specimen	*Fatigue strength, S_{so}*	*Range, $S_{so} - S_{su}$*
Fig. 1	20,000	16,500
Fig. 2	31,000	27,000
Fig. 3	14,000	10,500
Fig. 4	19,000	15,000
Fig. 5	13,000	8,500

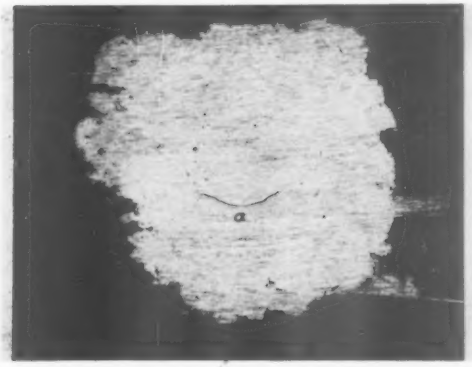


Fig. 6 Plug-welded specimen after 1,062,600 cycles of tensile stress between S_{su} = 3400 psi. and S_{so} = 13,600 psi. Note crack "a" at the edge of a weld

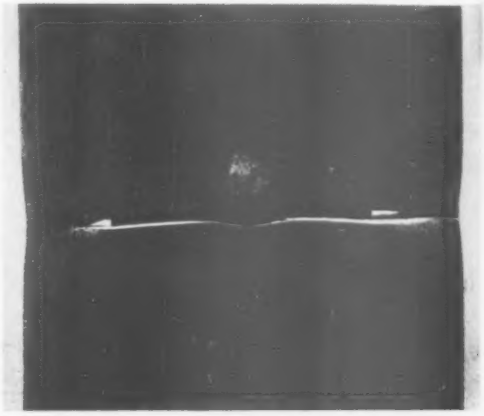


Fig. 7 Specimen shown in Fig. 4 after 889,200 cycles of tensile stress between S_{su} = 4400 psi. and S_{so} = 19,900 psi.

welds of the long straps when the load is applied. It is important to observe that the specimen in Fig. 2 (hole in the strap) has considerably higher fatigue strength than Fig. 1 (hole in the through plate). The results for Figs. 3 and 4 are in the same direction, the specimen with the holes in the strap having higher fatigue strength than the specimen with the holes in the through plate. Figures 6 and 7 show the type of failure. Cracks started at *a* at the edge of a plug weld.

2. SPOT WELDS (FIGS. 8 AND 9)

The specimens in Figs. 8 and 9 consisted of a through plate 4 in. wide on one side of which was welded a strap $3^1/_2$ in. long and 4 in. wide, or $9^1/_2$ in. long and $2^1/_2$ wide. The straps are fastened to the plate at one or three points by spot welds. The specimens in Figs. 8 and 9 were sawed from a large specimen $25^1/_2$ in. wide. Spot welding was done by the Siemens-Schuckert factory. The plates were from the same supply used in Section 1 and the properties are given in Section 1.2.

2.2 Results of Tests. Tensile strengths were 65,900 and 66,000 psi. for specimens in Fig. 8, and 69,200 and 67,000 psi. for those in Fig. 9.

The tensile strengths of both specimens were the same as the strength of the unwelded plate. Fracture occurred outside the welds. The spot-welded specimens, Figs. 8 and 9, had somewhat higher tensile strength than the plug-welded specimens, Figs. 1, 2 and 4. On the whole the joints in Figs. 8 and 9 had 100% efficiency.

The fatigue strengths at one million cycles were:

Specimen	S_u, *psi.*	S_m-S_u, *psi.*
Fig. 8	36,300	32,000
Fig. 9	17,100	12,800

The fatigue strength of the spot-welded specimen in Fig. 9 was higher than for the specimen in Fig. 2 (S_u = 31,000 psi.). The middle value for the plug-welded specimens of Figs. 3 and 4 was almost the same fatigue strength as for the spot-welded specimen in Fig. 9.

3. SPOT WELDS (FIGS. 10 TO 13)

3.1 Design of Joints. The specimens in Figs. 10 and 11 were made of plates 0.157 in. thick; the specimens in Figs. 12 and 13 were of plates 0.196 in. thick. There were four welds in each half of the joints in Figs. 10 and 12, and eight welds in each half of Figs. 11 and 13. The visible diameter of the spot welds was approximately the same: 0.43 to 0.55 in. for the four sets of specimens. Welding was performed in a factory of the Siemens-Schuckertwerke A.G. Plates about 26 x 17 to 25 in. were welded. The specimens were sawed from these plates in Stuttgart. All plates were sandblasted before welding.

The following welding data were supplied. For the joints in Figs. 10 and 11 the current was 13,500 and 15,000 amp., electrode pressure was 1320 and 1540 lb. and welding time was 2.1 sec. For Figs. 12 and 13 the current was 14,000 and 16,000 amp., pressure was 1540 and 1760 lb. and time was 2.5 sec. The spacing of the welds in Figs. 10 to 13 was not maintained exactly. For example, the distance from the middle of the out-

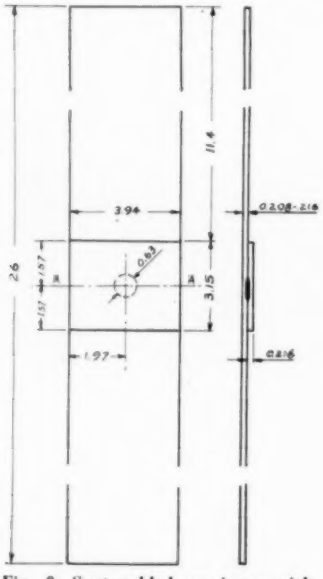


Fig. 8 Spot-welded specimen with mill scale. Dimensions in inches

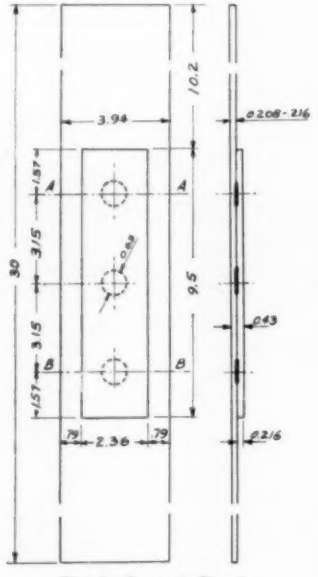


Fig. 9 Same as Fig. 8

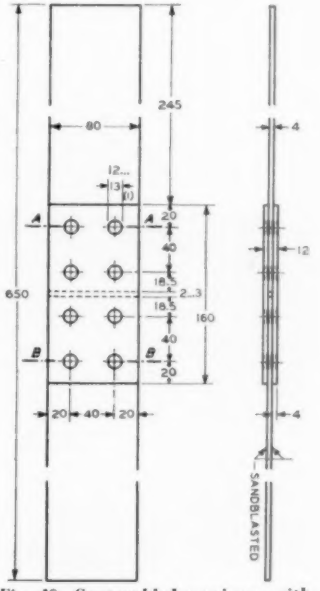


Fig. 10 Spot-welded specimen with sandblasted plates. Dimensions in millimeters. (1)Diameter of spots

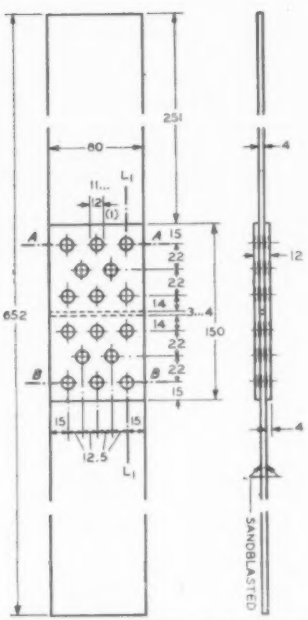


Fig. 11 Spot-welded specimen with sandblasted plates. Dimensions in millimeters

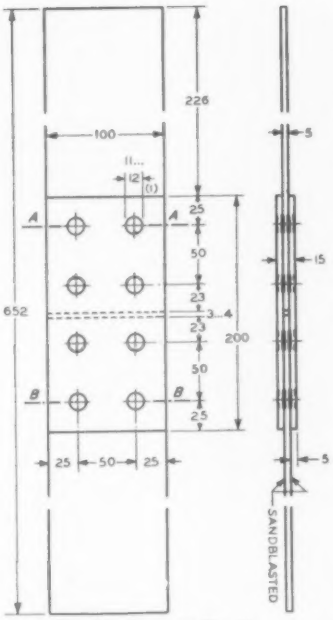


Fig. 12 Same as Fig. 11

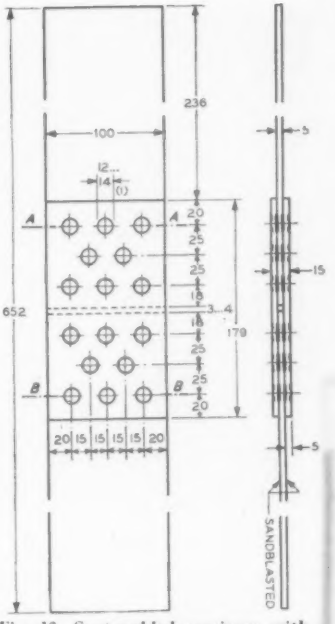


Fig. 13 Spot-welded specimen with sandblasted plates. Dimensions in millimeters. (d) = diameter of electrode indentation, front and back

side weld to the edge of the strap in the direction of loading was 0.71 to 0.95 in. (average = 0.83 in.) instead of 0.79 in. for the specimen in Fig. 10. The distance between welds in one half of the joint varied from 1.26 to 1.69 in. (average = 1.50 in.) instead of 1.57 in. Figure 14 is a photograph of the specimen in Fig. 12. The punch marks in Fig. 14 show the desired location of the center of the weld. The surface appearance of the welds is shown also in Fig. 14.

The tensile strengths calculated on the full cross section of the middle plate for specimens in Fig. 10 were 59,200 and 59,300 psi.; in Fig. 11, 60,000 and 60,500 psi.; in Fig. 12, 38,800 and 49,200 psi.; and in Fig. 13, 52,800 and 50,100 psi.

The specimens in Figs. 10, 11 and 13 broke outside the welds 3 to 6 in. away from sections A-A or B-B. The specimens in Fig. 12 failed by shear through the welds; the tensile strength of the plate was not reached.

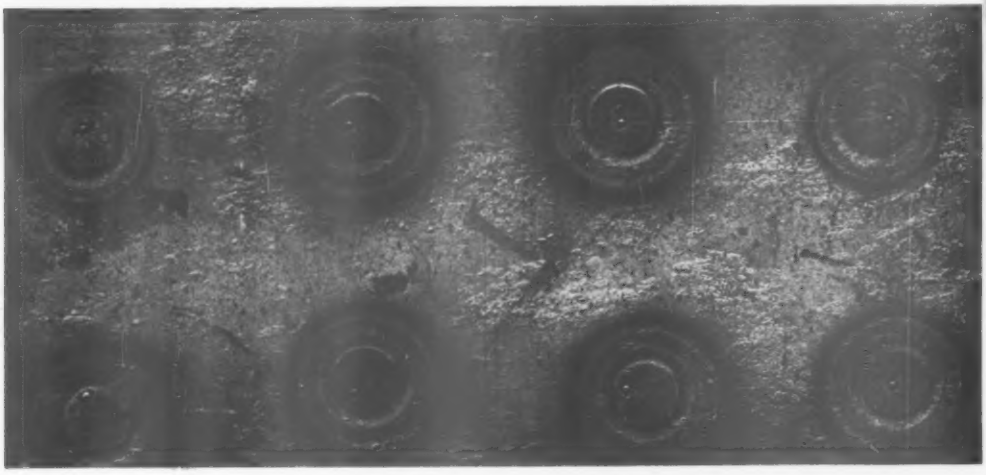


Fig. 14 Photograph of specimen in Fig. 12

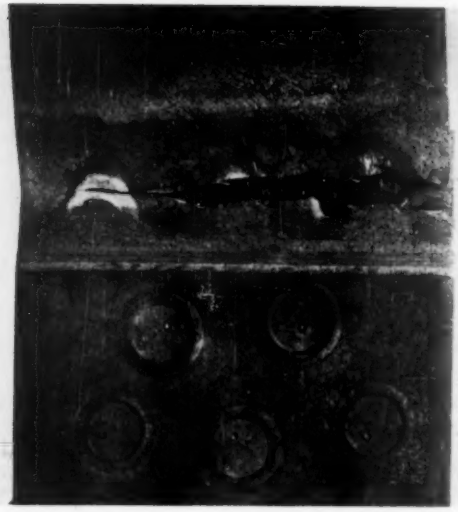


Fig. 15 Fracture of specimen in Fig. 13 after 1,285,400 cycles of tensile stress between a lower value S_{zu} = 4800 psi. and an upper value of S_{zo} = 19,900 psi. The strap has been machined away over the fracture

permissible shear stress on a weld is relatively low, much lower than for a rivet.*

The results of the fatigue tests are very instructive. As in the other fatigue tests the machines were operated at 660 cycles of load per minute. The lower tensile stress S_{zu} was 4300 psi. The fatigue strength S_{zo} (upper tensile stress) and the range of stress $S_{zo} - S_{zu}$ for one million cycles are listed in Table 2. The specimens made of plates 0.157 in. thick had higher fatigue strength than specimens made of plates 0.196 in. thick.

Table 2—Fatigue Results, Psi.

Specimens	*Fatigue strength, S_{zo}*	*Range, S_{zo}-S_{zu}*
Fig. 10	20,000	15,600
Fig. 11	22,700	18,500
Fig. 12	17,100	12,800
Fig. 13	20,600	15,600

Furthermore, the specimens with the larger number of spots, Figs. 11 and 13, had the higher fatigue strengths. Most of the fatigue failures occurred in one of the middle plates at a weld, as shown in Fig. 15. Specimens 243 and 244 (Fig. 12) failed through the welds.

Figures 16 and 17 further clarify the results, especially Fig. 17. The outer welds in Fig. 17 show complete fusion. The contact surfaces of both inner welds remain visible. The outer welds are satisfactory, the inner welds are not.

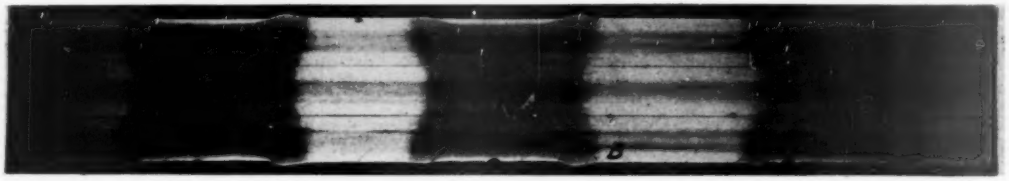


Fig. 16 Section through three welds in the specimen in Fig. 13

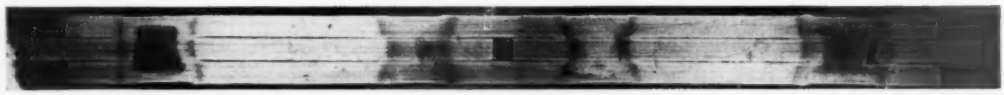


Fig. 17 Longitudinal section through four welds in the specimen in Fig. 11 after 1,057,200 cycles of tensile stress between S_{zu} = 4300 psi. and S_{zo} = 22,800 psi.

The shear stress on the weld calculated on the area of the indentation made by the electrode in the surface of the plate was 23,500–27,800 psi. for the specimen in Fig. 12. The shear stress on the welds in Figs. 10, 11 and 13 was much smaller. These results show that the

* Welds made in a satisfactory manner actually had a smaller cross section at the plate interface than the area of the electrode indentation.

Susceptibility to Graphitization of Modified Molybdenum Steel

A study of the influence of titanium, columbium and increased molybdenum on the susceptibility to graphitization of low-carbon molybdenum steels

by J. A. MacMillan and G. V. Smith

Abstract

Susceptibility to graphitization was studied in eight experimental heats containing 0.5 or 1.0% molybdenum and various amounts of titanium and columbium up to 1.0%, and two 1.0% molybdenum steels of commercial manufacture, all deoxidized with aluminum. Samples were normalized at 1650 or 2000° F. and bead welds laid down before exposing at 1025° F. for intervals of time totaling 10,000 hours (1.1 years). The plain molybdenum steels graphitized to varying degrees whereas no graphite was observed in those containing titanium or columbium.

Introduction and Summary

THE investigation reported here was designed to test the possibility of using titanium, columbium and molybdenum to inhibit graphitization in steels used at elevated temperatures. Since molybdenum is invariably used in steels to enhance creep strength, at moderate operating temperatures, a base composition of 0.5% molybdenum was chosen.

Eight experimental heats containing 0.5 or 1.0% molybdenum and various amounts of titanium or columbium up to 1%, and two 1% molybdenum steels of commercial manufacture were studied. All were deoxidized with a relatively large amount of aluminum. Samples were normalized at 1650 or 2000° F. for $^1/_2$ hr., after which two weld beads (one with a relatively wide heat-affected region; the other with a relatively narrow heat-affected region) were deposited on each sample. Half of each sample was postheated at 1300° F. for 4 hr. and air cooled.

After exposure at 1025° F. for intervals of time totaling 10,000 hr. (1.1 years), the six steels containing titanium or columbium showed no signs of graphitization in any condition of initial or post treatment, whereas the other four steels graphitized to varying degrees depending upon the previous treatment.

Steels No. 1 (0.57% Mo, experimental heat used for control purposes), No. 9 (1.10% Mo, commercial open-hearth heat) and No. 10 (1.36% Mo, 200-lb. electric furnace heat) graphitized quite readily, whereas steel No. 8 (1.08% Mo, experimental heat) was comparatively stable, developing only a few small and scattered particles of graphite after 10,000 hr. at 1025° F. Steel No. 8 contained the smallest percentage of aluminum of any of the steels which graphitized. The most graphite was found in steel No. 10 which had the highest carbon and aluminum content.

In general, graphite formed more readily in samples initially normalized at 1650° F. than in those normalized at 2000° F. Post heating at 1300° F. reduced the number of graphite nuclei considerably. More graphite was found in the heat-affected zones of the weld beads deposited with a relatively steep temperature gradient. Other conditions remaining constant, more graphite developed with each increasing increment of time.

The progress and extent of graphite formation are indicated in Table 3 and in the photomicrographs of Figs. 2 and 3.

Acknowledgment

The possible inhibition of graphitization by additions of titanium or columbium was suggested by Dr. R. E. Zimmerman, Vice-President, Research and Technology, United States Steel Corp. of Delaware. The Research Laboratory of National Tube Co. prepared seven of the experimental heats. Miss S. H. Brambir and W. G. Benz and E. J. Dulis assisted in the experimental work.

Materials

The steels studied had the compositions given in Table 1.

J. A. MacMillan was formerly associated with the Research Laboratory, United States Steel Corp. of Delaware, Kearny, N. J.; now returned to National Tube Co., Lorain, Ohio. G. V. Smith is with the Research Laboratory, United States Steel Corp. of Delaware, Kearny, N. J.

Table 1—Identification and Composition of Steels

Steel	*C*	*Mn*	*P*	*S*	*Si*	*Al*	*Al_2O_3*	*Mo*	
1	0.082	0.50	0.016	0.028	0.293	0.029	...	0.57	...
2	0.088	0.61	0.016	0.027	0.359	0.034	...	0.53	0.25 Ti
3	0.093	0.60	0.018	0.029	0.425	0.031	...	0.56	0.47 Ti
4	0.087	0.61	0.016	0.029	0.344	0.033	...	1.05	0.25 Ti
5	0.097	0.60	0.018	0.030	0.348	0.032	...	0.95	0.50 Ti
6	0.076	0.60	0.015	0.027	0.378	0.047	...	0.52	1.08 Cb
7	0.081	0.62	0.016	0.028	0.434	0.046	...	0.98	1.12 Cb
8	0.14	0.54	0.013	0.021	0.17	0.012*	0.019*	1.08	...
9	0.16	0.43	0.015	0.013	0.16	0.029*	0.018*	1.10*	...
10	0.21	0.38	0.017	0.025	0.06	0.18*	0.039*	1.36*	...

* Check analysis

The series of molybdenum, titanium or columbium steels (steels 1 to 7) were induction furnace heats of approximately 20 lb. each. They were deoxidized with 2 to 3 lb. total aluminum per ton of steel, and commercial melting practice was duplicated as closely as possible. For the titanium additions a high-silicon, low-aluminum, ferro-titanium alloy containing approximately 0.04–0.05% C, 4% Al, 8% Si and 42% Ti was used. The ingots from these heats were forged into 1-in. square bars.

The other three steels were selected from stock in the laboratory. All were in the as-forged condition in 1-in. diameter round bars. Steel No. 10 was a 200-lb. electric furnace heat made at Ellwood Works of National Tube Co. Steel No. 9 was a 95-ton basic open-hearth melt, made at Lorain Works of National Tube Co.; it was deoxidized with silicon plus aluminum. Steel No. 8 was a laboratory induction furnace heat prepared by National Tube Co. Research Laboratory; it was deoxidized with silicon and aluminum.

Heat Treatment and Welding

The original specimens, 4 in. in length and about 1 sq. in. in cross section, of each steel were normalized for ½ hr. at 1650 or 2000° F. The round samples were machined flat on two opposite sides and all scale was removed from the square samples by grinding in preparation for welding.

After the weld beads were deposited according to the schedule shown in Table 2, half of each specimen was given a post treatment of 4 hr. at 1300° F. and then air cooled to determine whether this treatment is beneficial in inhibiting graphitization. A macrograph of one of the welded samples is shown in Fig. 1.

Table 2—Schedule of Welding

	First Bead	*Second Bead*
Amperes	180	100
Volts	24–25	23–24
Arc-travel speed	5 in. per minute	10 in. per minute
Pre-weld temperature	80 ° F.	80° F.
Electrode	3/16-in. diameter E7010 electrode	1/8-in. diameter E7010 electrode

All samples were then heated in a muffle-type furnace for a total time of 10,000 hr. (1.1 years), sections being taken from each sample at intervals of 2000, 5000 and 10,000 hr.

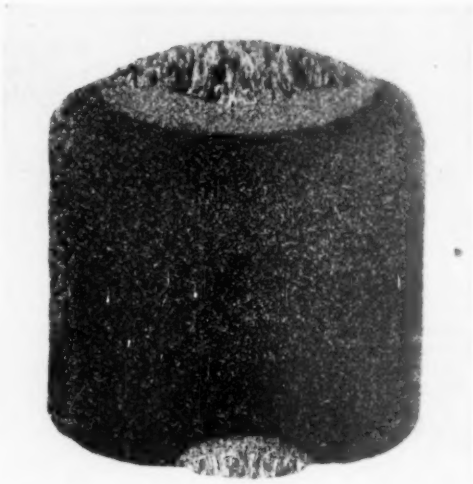


Fig. 1 Cross section of welded specimen characteristic of those used in this investigation. Macro etch of nital plus picral. Steel 5. × 2

Discussion of Results

No graphite was observed in any of the steels containing titanium or columbium, but the four plain molybdenum steels, including the control steel of the experimental series, did graphitize to varying degrees under different conditions of previous heat treatment. An attempt has been made in Table 3 to describe the progress of graphitization of these four steels. The photomicrographs of Figs. 2 and 3 illustrate the degree to which graphitization proceeded in several samples.

When graphite formed in these steels it tended to concentrate in the A_1 region of the heat-affected zone of the welds. More graphite was found in the heat-affected zone of the small bead than in that of the large bead, probably as a result of the faster cooling rate.

More graphite particles formed in steel No. 10, Figs. 2 (*a*) and (*b*), than in any of the others and there was little difference in the amount of graphite in the

heat-affected zone of the small bead whether initially normalized at 1650 or 2000° F. This was not true for the large bead which followed the general pattern, in that less graphite formed when the steel was normalized at 2000° F. The fact that so much graphite formed that little difference resulted from the two normalizing temperatures might be explained by the composition of this steel, which was higher in carbon and aluminum than the others. A check analysis of the aluminum content showed 0.18% as compared to a maximum of 0.03% in the other steels showing graphite. The aluminum content of this steel is unusually high, presumably because it is an experimental melt.

After 10,000 hr. exposure a considerable amount of graphite developed in steel No. 9 which had been normalized at 1650° F. but not postheated, Figures 2 (*c*) and (*d*). This steel was of basic open-hearth manufacture deoxidized with silicon plus aluminum. The individual nodules were much larger than those which formed in the other steels and in some places assumed a chain-like appearance. The post treatment of 4 hr. at 1300° F. followed by an air cool was quite effective in reducing the number of graphite nuclei in this steel as well as in the other three steels.

Steel No. 8 showed good resistance to graphitization considering the fact that its composition was nearly the

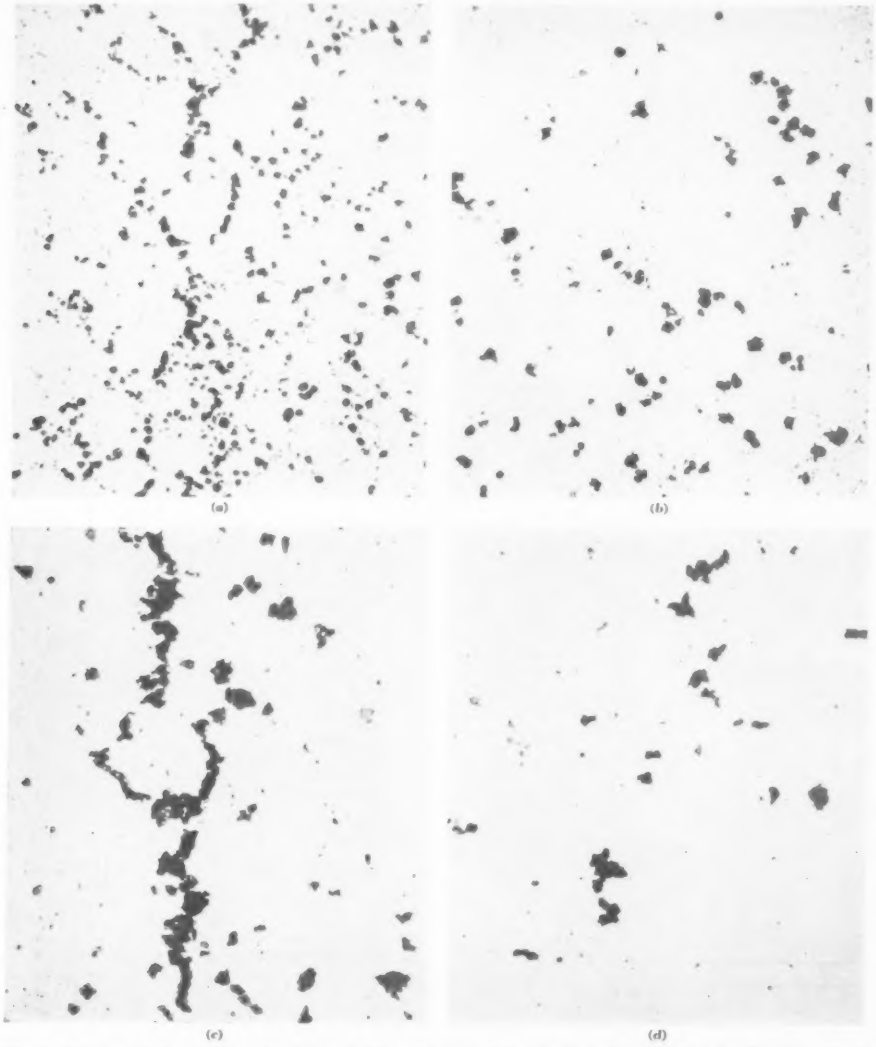


Fig. 2 Graphite in heat-affected zone of small and large weld beads of steels 9 and 10, initially normalized ½ hr. at 1650° F., after 10,000 hr. exposure at 1025° F., picral etch. 500 ×

(*a*) Steel 10. Small weld bead. (*b*) Steel 10. Large weld bead. (*c*) Steel 9. Small weld bead. (*d*) Steel 9. Large weld bead

same as steel No. 9. Only after 10,000 hr. exposure was any graphite observed, and then the particles were very small, few in number and scattered throughout the specimens in three of the four conditions of heat treatment. The aluminum content was 0.012%, the lowest of any of the steels, which presumably explains why it graphitized less readily.

Steel No. 1, the low carbon–0.5% molybdenum steel used for control purposes in the titanium and columbium experimental series, graphitized in a number of conditions of heat treatment (see Table 3). This steel was extremely dirty and the graphite particles were very small which made their identification difficult (see Fig. 3). The low carbon content (0.082%) probably was a limiting factor in the growth of the graphite particles as there was little difference in their size between 5000 and 10,000 hr. exposure.

Located near the center of each specimen of Steel No. 1 there was a finely dispersed inclusion of unknown nature (though presumed to be alumina) and graphite was found associated with it in the 2000° F. normalized condition only (see Fig. 4). The amount of this graphite was greatly reduced by the post treatment at 1300° F.

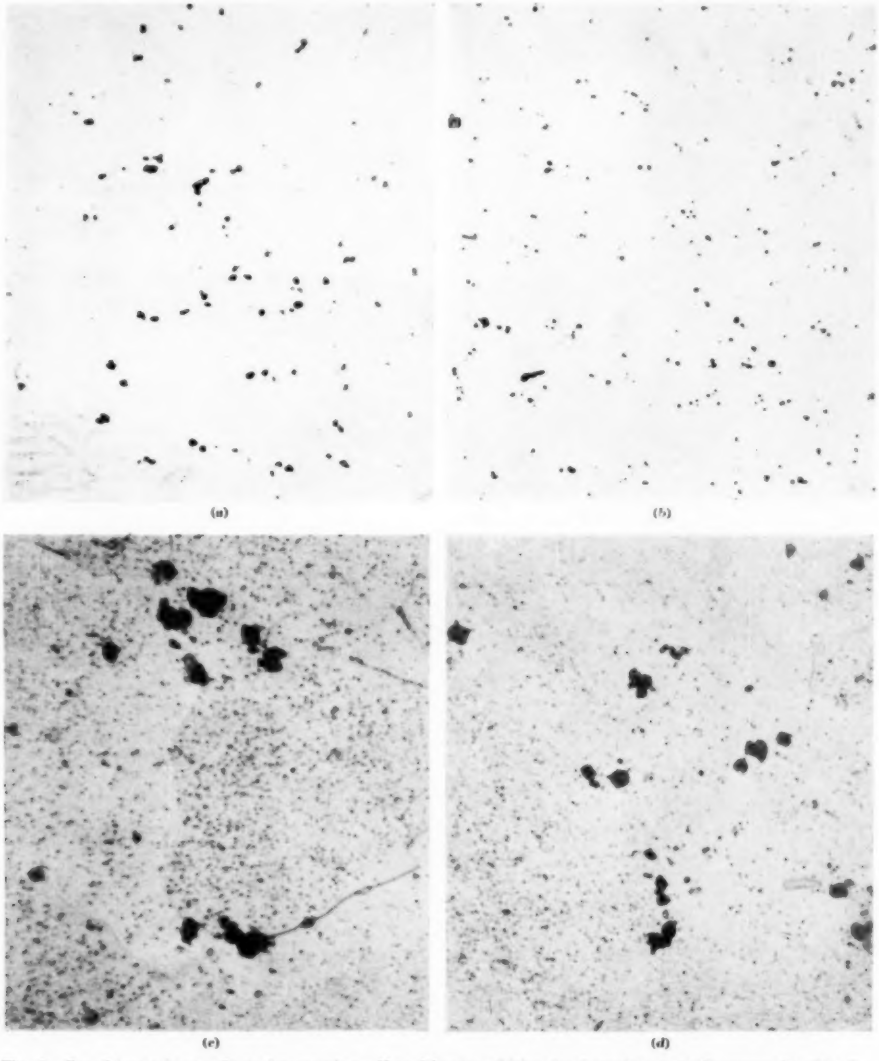
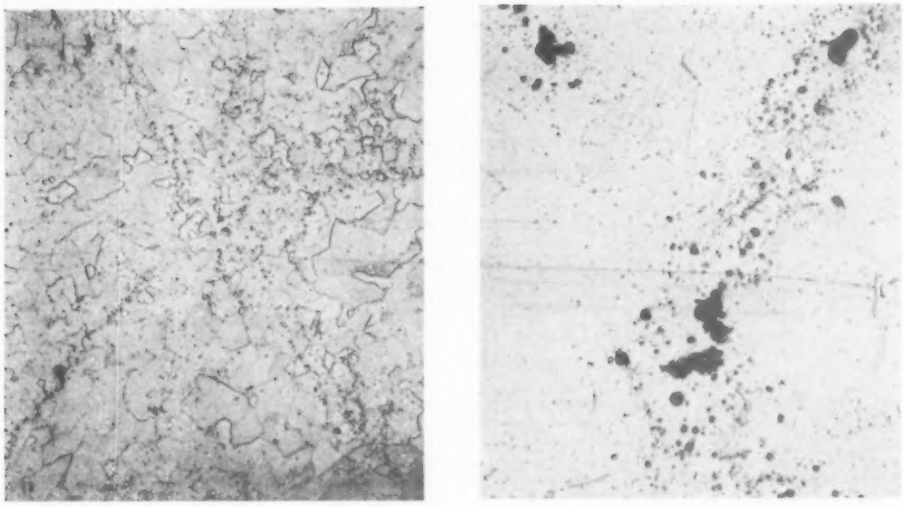


Fig. 3 Graphite in heat-affected zone of small and large weld beads of steel 1, initially normalized ½ hr. at 1650° F., after 10,000 hr. exposure at 1025° F., picral etch

(a) Small weld bead. × 500. (b) Large weld bead. × 500. (c) Small weld bead. × 2000. (d) Large weld bead. × 2000



(a) × 100 (b) × 1000

Fig. 4 Graphite associated with inclusion near center of specimen in steel 1, initially normalized ½ hr. at 2000° F., after 10,000 hr. exposure at 1025° F., picral etch

Table 3—Progress of Graphite Formation in the Four Molybdenum Steels Which Graphitized

Steel No.	*Hours exposure at 1025° F.*	*Normalized, 1650° F.*	*Normalized, 1650° F. Postheat, 1300° F.*	*Normalized, 2000° F.*	*Normalized, 2000° F. Postheat, 1300° F.*
1	2,000	SB, LB	.....	Incl.	Incl.?
	5,000	SB, LB, BM?	SB, LB	Incl.	SB? BM? Incl.
	10,000	SB, LB (see Fig. 2)BM	SB, LB, BM	SB, LB, BM, incl. (see Fig. 4)	SB, LB, BM, Incl.
8	2,000	.....	.....	.....	.....
	5,000	.....	.....	.....	.....
	10,000	SB, LB, BM*	SB, LB, BM*	SB, LB, BM*	(SB, LB, BM)?
9	2,000	SB, LB	.....	.....	.....
	5,000	SB, LB	.....	.....	.....
	10,000	SB, LB (see Fig. 3)BM	SB, LB	SB, LB, BM	.....
10	2,000	SB, LB	SB, LB	SB, LB	SB
	5,000	SB, LB, BM	SB, LB	SB, LB	SB
	10,000	SB, LB (see Fig. 3) BM	SB, LB, BM	SB, LB, BM	SB, LB, BM

Symbols: SB—Graphite concentrated in A_1 region, heat-affected zone of small weld bead (severe welding conditions). LB—Graphite concentrated in A_1 region, heat-affected zone of large weld bead (normal welding conditions). BM—Graphite particles scattered in base metal of sample. Incl.—Graphite associated with inclusion in Steel No. 1 (see Fig. 4).?—Presence of particles which were unidentifiable but which might be graphite. *—Graphite particles very small and few in number, scattered in heat-affected zones and base metal.

Steel No. 1, as well as the titanium and columbium steels, were 20-lb. induction furnace heats similarly melted and deoxidized with 2 to 3 lb. total aluminum per ton of steel. Since no graphite formed in any of the titanium or columbium steels it may be assumed that 0.25% titanium or 1.0% columbium (and presumably less of this element) along with 0.5% molybdenum is sufficient to prevent graphitization in these low carbon steels, at least up to 10,000 hr. exposure at 1025° F. It should be emphasized, however, that these steels represent laboratory heats, which do not always accurately foretell the behavior of commercial heats.

Fractographic Examination of Ship Plate

A new microscope technique called Fractography is applied to the problem of classifying ship steel in terms of toughness and transition temperatures

by C. A. Zapffe, C. O. Worden and F. K. Landgraf

INTRODUCTION

SHORTLY before the recent war, a new microscope technique was discovered by the senior author which permits direct observation and study at high magnification of the path which cleavage follows in traversing the individual grains within a solid such as metal.[1,2,3]

In 1944, this technique, referred to as "fractography," was applied to a study of iron-chromium alloys. The results were presented before the first postwar meeting of the Société Francaise de Métallurgie in 1946[4] and carried as their particular contribution what seemed to be a marked characteristic of the individual cleavage facet directly related to the property commonly referred to as "toughness"—a property of great engineering importance which has eluded dependable definition for many years.

In September 1947, by order of the Bureau of Ships, Navy Department, specimens of nine "pedigreed" ship-plate steels were supplied this laboratory for fractographic examination. These were: Q, A, DR, DN, BR, BN, H, C and E. Later Steel N was also supplied.

From the first nine steels, fractographs of typical structures were obtained; and solely upon the basis of the toughness indicated in the fractograph, the steels were classified. In fact, a point was made to keep the fractographers completely uninformed, until after the test, of the specimen's identity or even of the general history of these steels as explored previously in other laboratories.

With these restrictions and with the general handicap of inexperience with the subtle cleavage structures in steel, the observers ranked the first nine steels in almost exact agreement with the order of toughness as determined by the slip-transition temperature* studies with 72-in. plate.[5]

While the results were extremely encouraging, there was an uncertainty about the H steel; and the N steel, studied later, clearly disclosed the activity of factors which do not express themselves on the cleavage pattern and which therefore must be accounted for if fractography is to be usefully applied.

To evaluate these factors and to present fractography as a possible tool of importance in appraising the cleavage characteristics and toughness of metal, specifically ship plate, the cleavage patterns of ten of the standardized steels will now be described.

EXPERIMENTAL METHOD

Small pieces, approximately $^1/_4$ in. square cross section and 1 in. long, were hand-sawed from the standard steels and lightly notched with the saw blade near their centers. Specimens cut from each of the three directions of several plates were first studied for variations in pattern among the three possible longitudinal and transverse sections. Distinctions from plate to plate seemed equally expressed in any of the three; but, because of certain differences among the three within any one plate, all future specimens were uniformly sectioned through the thickness of the plate and fractured longitudinally-horizontally near the plate center.

In fractography, one is less interested in the exact temperature at which a mechanical property changes than in the architecture of the grain which may allow the event, or be associated with it. Consequently, all specimens were purposefully rendered brittle before fracturing so that the individual grain would cleave from one edge to another without segmentation from interposed slip. Segmentation involves one section of the total pattern faulting along one or more of the traces in that pattern until the entire section is removed from the field of focus. The action thereby both decreases the field available for study and destroys the

C. A. Zapffe is a Consulting Metallurgist. **C. O. Worden** and **F. K. Landgraf** are Research Metallurgists at the laboratory of the senior author in Baltimore, Md.

Research for this paper was conducted in the laboratory of the senior author under contract with the Office of Naval Research.

* Because of the conflict of the term "transition temperature" with the conventional metallurgical reference to change of phase, the term "slip-transition temperature" is chosen for usage here. Whether measured by ductility or impact, the phenomenon under discussion fundamentally concerns the operation or nonoperation of the slip mechanism in metals and is therefore properly so designated.

evidence (trace) of the segment as an original structural unit within the grain.

For embrittling, or eliminating the slip mechanism, several techniques can be used. Immersion in liquid nitrogen (−196° C.) served here, unless an exception is noted. This utilizes a temperature far below the slip-transition temperature, of course, but for reasons just given. The specimen was kept immersed for a period of five minutes after cessation of boiling, removed with refrigerated tongs, placed immediately in a vise and broken with a hammer blow. The fractured pieces were dropped into ether to prevent rusting from condensation of moisture, after which they were removed and mounted in the fractographic stage shown in Fig. 1. This stage is the preliminary model of a standardized stage being produced by the Bausch and Lomb Optical Co. Its adaption to the microscope is illustrated in Fig. 2. A cup containing plasticene holds the specimen in an inverted position, fracture facing the lens. Two concentric shells of the stage then allow rotating the specimen through a wide angle without losing focus. By these manipulations the individual facets are readily perpendicularized and brought into view as desired.

Fig. 1 Fractographic stage used for mounting, holding, and orienting the specimen. The specimen, held by plasticene in the mounting cup, exposes its fractured face at the beometric center of the two concentric half-spheres, allowing orienting movements of the individual facets without loss of focus. (Natural size).

OBSERVATIONS

The Toughness Pattern as Disclosed by Iron-Chromium Alloys

Chromium added to iron closes the gamma loop and accordingly provides alloys ranging from fully martensitic microstructures to fully ferritic. The martensitic structure, as in the hardened 4–6 chromium steels, Types 501 and 502, is known to have high strength, relatively good notch-impact resistance and general toughness. The ferritic grades, to the decided contrary, are notorious for their low notch-impact resistance and lack of toughness. These are typified by the Type 442 (21% chromium) and 446 (27% chromium) stainless steels. In between the two extremes lie such intermediate steels as Type 430 stainless steel with a flexible chromium content ranging from 14 to 18% for the purpose of allowing the customer to gain mechanical properties on the low side of chromium content with sacrifice of corrosion resistance, or vice versa. While the notch-impact resistance of ship plate suddenly decreases at a critical temperature referred to here as the slip-transition temperature, the notch-impact resistance of iron-chromium alloys similarly loses at a critical chromium content near 16%.[8]

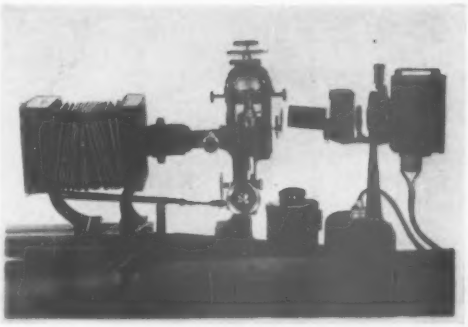


Fig. 2 Adaption of the fractographic stage to the microscope

In Fig. 3, a typical pattern of a cleavage facet in martensitic chromium steel is shown. The chromium content is 7.7%; and the rough, highly inflected path forced upon cleavage through this metal clearly illustrates pictorially the resistance of the material to deformation and fracture. This "oak-leaf" or "coral"

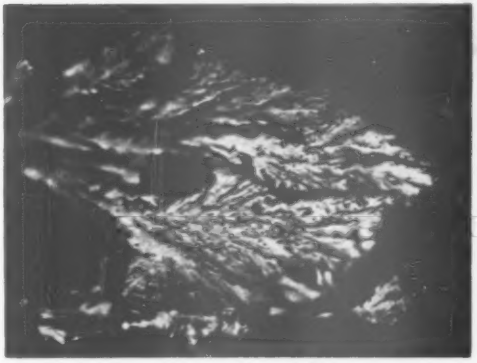


Fig. 3 Fractograph of a cast iron-chromium alloy containing 7.70% chromium and 0.10% carbon, homogenized for 40 hr. at 875° C. and cooled in air. This is a pattern of distorted cleavage, and hence of "toughness." 2000 ×; reduced by 1/3 in reproduction

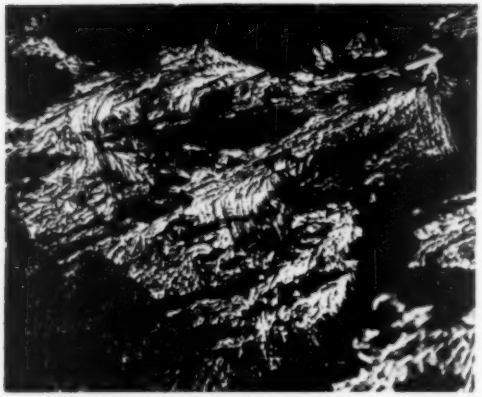


Fig. 4 Fractograph of alloy containing 17.16 Cr and 0.10 C treated similarly to that in the preceding figure. Here the transition from toughness to nontoughness shows as a meandering pattern of mild distortion, greater expansiveness, and increased flatness. There is also an indication of crystallographic markings. 300 ×; reduced by 1/3 in reproduction

pattern, then, can be temporarily chosen as a pattern of toughness.

In Fig. 4, the chromium content of an otherwise similar alloy has been increased to 17.16%. The martensitic phase has almost disappeared; the thermal hardenability is accordingly very slight, and the alloy is at the very boundary for chromium content (near 16%) where notch-impact resistance rapidly declines. The fractograph expresses this relationship through a considerably increased expansiveness of the individual facets, an increased flatness, and an appearance generally in keeping with a more ready cleavage than for the 7.70% chromium alloy. The flatness of the facet is principally broken by several mild contortions—in appearance suggestive of a mophead—and by broad pits probably caused by martensite fractions which have pulled away.

In the greatest contrast to Fig. 3, the fractograph in Fig. 5 shows a complete disappearance of the distorted path of toughness, and even of the vestiges of toughness illustrated by the meandering pattern of the previous figure. Instead, the facet is expansive, flat and extremely angular, or crystallographic. The chromium content is now 28.67%. The standard stainless steel having virtually this composition is Type 446, notorious for its low resistance to cleavage by impact. Note the marked angularity at 45 and 90°, indicating that this is a {001} cleavage plane which is being viewed. Also, note the vastly intricate substructure, which contains the secret of plastic deformation and phase precipitation and has never been explored. This substructure is all intragranular, of course, the grain boundary here lying well outside the field of the fractograph.

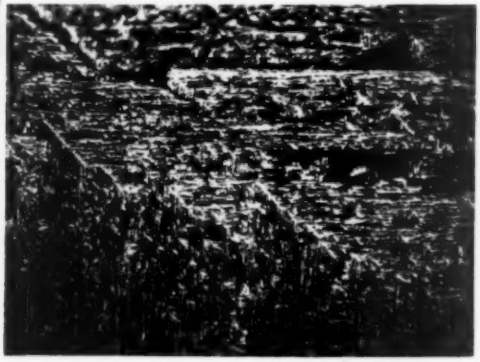


Fig. 5 Fractograph of alloy containing 28.67 Cr and 0.11 C treated as in preceding figures. Maximum flatness, great expansiveness, and marked crystallographic registrations on this pattern disclose the low resistance to notch-impact for which this alloy as a commercial grade of stainless steel (Type 446) is notorious. 750 ×; reduced by 1/3 in reproduction

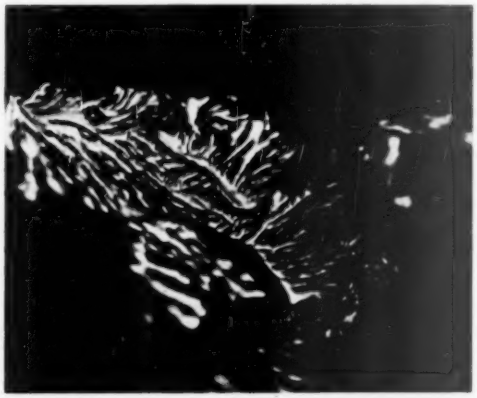


Fig. 6 Fractograph of typical facets in Steel Q, showing the coral pattern indicative of relative toughness. 1250 ×; reduced by 1/3 in reproduction

Fig. 7 Fractograph of Steel Q, again revealing the toughness pattern, but on larger facets than those of the preceding figure. 1250 ×; reduced by 1/3 in reproduction

Fig. 8 Fractograph of Steel BR, showing somewhat the pattern of toughness found in Q, but with visibly less roughness and hence less resistance to cleavage. 1500 ×; reduced by 1/3 in reproduction

Some Factors Underlying Toughness

Before attempting to compare cleavage patterns among random types of steels, certain principal factors undergirding toughness as a property must be distinguished.

First, atomic cohesion itself must constitute a fundamental factor, the strength of iron differing basically from the strength of iron alloy. Second, an enforced change in cleavage traverse, evident as an inflection on the fractographic pattern, must contribute to toughness. We may then list as more or less independent factors: (I) atomic cohesion, (II) transgranular traverse and (III) intergranular traverse.

That is, the force required for cleavage comprises (*a*) a basic increment for overcoming interatomic cohesion between atoms which are in good contact, (*b*) a second increment related to design obstacles (fractographic pattern) within the individual grain and (*c*) a third increment related to the obstacle of the grain boundary and the change in crystallographic direction involved in passing from grain to grain.

In comparing fractographic patterns for toughness rating, the first and third factors, composition and grain size, must either be held constant or accounted for. Fractography readily discloses the variation of toughness with heat treatment for a given steel, and it may disclose subtle variations not previously identified; but the relationship of the cleavage pattern to Factor I is a matter on which we are not yet prepared to comment.

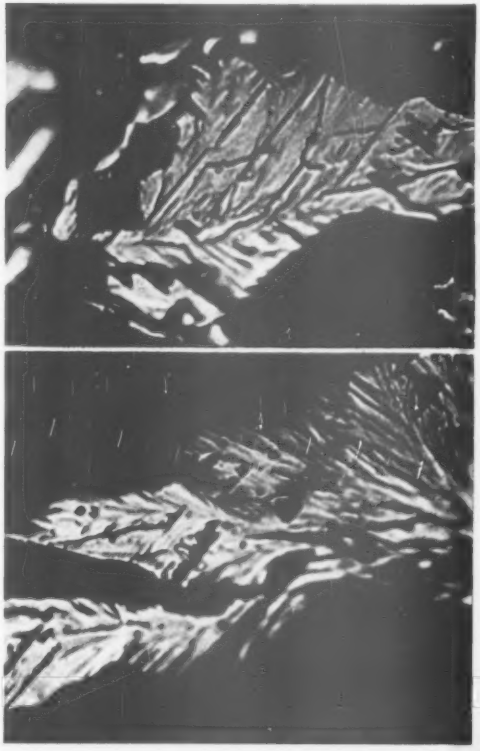


Fig. 10 Fractographs of Steel DR, showing increased flatness and an incipient block-like pattern of crystallographic nature, generally suggestive of Fig. 5, and particularly of the pattern of hydrogen-embrittled ferrite. 1500 ×; reduced by 1/3 in reproduction

Fig. 9 Fractograph of Steel BN, showing an increased flatness of cleavage traverse and the appearance of crystallographic markings at 45 and 90°. Normalizing has decreased the toughness of the B steel. 1500 ×; reduced by 1/3 in reproduction

For these reasons, Steel N, and also H, will be reserved for a later consideration because their composition complicates a preliminary study. The remaining steels are sufficiently similar in composition to fix Factor I; and Factors II and III can be evaluated from the fractographs.

In Table 1 the ten steels are listed on the basis of composition, condition, mechanical properties and slip-transition temperatures as determined by three

types of tests described in publications of the National Research Council.[7–13]

Fractography of the Standard Steels

Steel Q. Among the plain carbon steels listed as the first eight specimens in Table 1, Steel Q has been found to have the lowest slip-transition temperature. Typical fractographs are presented in Figs. 6 and 7.

All four facets show consistently a pattern of distortion similar to that previously shown in Fig. 3. This is the oak-leaf or coral pattern, and designates the Q steel as a relatively tough steel, which is completely in keeping with the results both of Charpy impact tests and of tensile tests on 12-in. plate reported in Table 1.

Steel BR. In keeping with the broad designations of Table 1 that BR is less tough than Q, the fractographs in Fig. 8 show something of the nature of the coral pattern of toughness, but with a definitely less rugged cleavage traverse. The terrain is undulating rather than rough, with suggestions of smoothness. Crystallographic markings, however, so strongly characterizing the pattern of nontoughness in the previous Fig. 5, are virtually absent. The path of separation through this metal has therefore been less difficult than through Q, but still offering noteworthy resistance, which is consistent with the results listed in Table 1.

Steel BN. In the patterns of Steel BN, illustrated in Fig. 9, the traverse of cleavage is visibly of a different type, and suggestive of still greater flatness and easier traverse than in BR. This is consistent with the results of the 12-in. plate tests and the impact tests in Table 1. The 72-in. plate tests listed in the table reveal no important differences between BR and BN.

However, from the fractographic patterns, we conclude that normalizing the B steel is unfavorable to toughness. The basis for the conclusion lies in the greater flatness of the facet, and in the significant crystallographic markings[1] at 45 and 90° now appearing.

Table 1—Description of Specimens*

Ship steel	Type steel	Condition	Chemical analysis C	Mn	P	S	Si	Al	Ni	Cu	Cr	Mo	Sn	N_2	Average physical properties—Tensile strength, psi.	Yield point, psi.	Elongation % in 8 in.	Slip-transition temperature (°F.)—Tensile test 12-in. plates	72-in. plates	Charpy impact standard V notch
Q	.....	Water-quenched and drawn	0.22	1.13	0.011	0.030	0.05	0.008	0.05	0.13	0.03	0.006	0.018	0.006	72,450	46,600	45.0†	+5°/−10°	?	−5°
			0.23	1.05																
BR	Semikilled	As-rolled	0.18	0.73	0.008	0.030	0.07	0.015	0.05	0.07	0.03	0.006	0.012	0.005	59,600	35,800	26.0	5°	32°	10°
			0.18	0.72																
			0.15	0.76	0.010	0.030	0.04													
BN	Semikilled	Normalized	0.18	0.73	0.011	0.030	0.04	0.013	0.06	0.08	0.03	0.006	0.015	0.006	58,900	34,800	32	15°	31°	30°
			0.18	0.72																
			0.15	0.76	0.010	0.030	0.04													
DR	Fully killed	As-rolled	0.22	0.55	0.013	0.024	0.21	0.020	0.16	0.22	0.12	0.022	0.023	0.006	65,100	37,600	32.3	40°	30°	45°
			0.19	0.52																
			0.19	0.52	0.011	0.02	0.24													
DN	Fully killed	Normalized	0.19	0.54	0.011	0.024	0.19	0.019	0.15	0.22	0.12	0.021	0.025	0.006	59,500	34,800	31.1	5°	28°	30°
			0.19	0.52																
			0.19	0.52	0.011	0.02	0.24													
A	Semikilled	As-rolled	0.26	0.50	0.012	0.039	0.03	0.012	0.02	0.03	0.03	0.006	0.003	0.004	59,910	37,950	33.5*	25°	35°	90°
			0.25	0.47																
			0.23	0.47	0.011	0.042	0.02													
C	Semikilled	As-rolled	0.24	0.48	0.012	0.026	0.05	0.016	0.02	0.03	0.03	0.005	0.003	0.009	67,400	39,000	25.5	90°	90°	100°
			0.25	0.49																
			0.24	0.49	0.015	0.033														
E	Rimmed	As-rolled	0.20	0.33	0.013	0.020	0.01	0.009	0.15	0.18	0.09	0.018	0.024	0.005	57,000	30,000	31.8	90°	100°	150°
			0.23	0.39																
			0.23	0.39	0.019	0.032	0.008													
H	Fully killed	As-rolled	0.18	0.76	0.012	0.019	0.16	0.053	0.05	0.09	0.04	0.006	0.004	0.004	63,100	39,800	27.0	−15°	20°	0°
			0.16	0.85																
			0.17	0.82	0.022	0.024	0.15	0.056				0.40								
N	3½% Ni	As-rolled	0.17	0.53	0.011	0.020	0.25	0.077	3.39	0.19	0.06	0.025	0.017	0.005	79,700	58,600	30.0	−64°	−45°	−50°
			0.13	0.49																
			0.13	0.49	0.018	0.027	0.22	...	3.34											

* Data from Refs. 7–13.
† Elongation % in 2 in.

Fig. 11 Cleavage pattern of Steel DN, showing elimination of crystallographic characteristics apparent in the as-rolled pattern in the previous figure. 1250 ×; reduced by 1/3 in reproduction

Steel DR. In the as-rolled condition, Steel D introduces a pattern not observed in the preceding specimens. The fractographs in Fig. 10 show unusual flatness, with crystallographic markings so pronounced that their intersections lead to block-like hiatuses reminiscent of the previous Fig. 5, and more specifically of the facets in hydrogen-embrittled ferrite.[1] This latter observation shall be kept in mind, for fully killed steel is more liable to hydrogen absorption than semikilled steel both because its oxygen pressure is lower and because no flushing action from CO gas takes place.

In agreement with the results of the 12-in. plate tests and the impact tests (Table 1), we conclude that the D steel is inferior to the B steel from the standpoint of toughness. The results of the 72-in. plate tests do not distinguish between them.

Steel DN. Normalized, this same D steel presents the patterns shown in Fig. 11. Though the facets remain markedly flat, the block-like markings and strong crystallographic characteristics are absent.

On the basis of the fractographic pattern, we conclude that normalizing has improved Steel D. This conforms with the results of all tests listed in Table 1.

Furthermore, on the basis of the significance of the block-like markings indicated by earlier work with hydrogen-embrittled ferrite[1], we draw attention to the present paradox wherein the normalizing treatment is

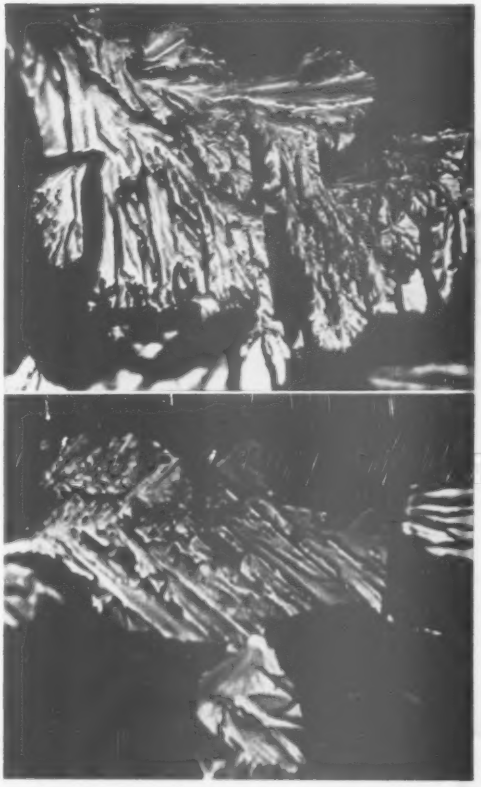


Fig. 13 Facets of Steel C, disclosing advanced block structure cleavage characteristics. 1250 ×; reduced by 1/3 in reproduction

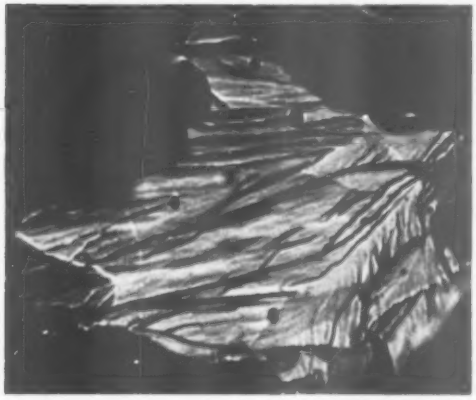


Fig. 12 Facets of Steel A showing a pattern similar to DR in Fig. 10, but having greater expansiveness. 1250 ×; reduced by 1/3 in reproduction

unfavorable to the semikilled Steel B, but favorable to the fully killed Steel D; and we submit that these observations have a ready explanation if one will grant a role of hydrogen to slip-transition temperature phenomena.

That is, normalizing in itself can be understood to decrease toughness slightly by relieving those vestigial distortions in the hot-rolled material which relate distantly to the martensite action creating the coral pattern in quenched-and-drawn Steel Q. Steel EN is accordingly inferior to BR in cleavage characteristics. But normalizing also provides an opportunity for hydrogen to escape from the metal, or at least to

redistribute itself in a manner counteracting harmful segregation. Steel D, which may have a harmful hydrogen content, then shows an over-all improvement from normalizing because of the counteracting hydrogen

Fig. 14 Facets of Steel E, showing great flatness and expansiveness and pronounced crystallographic markings. 975 ×; reduced by 1/2 in reproduction

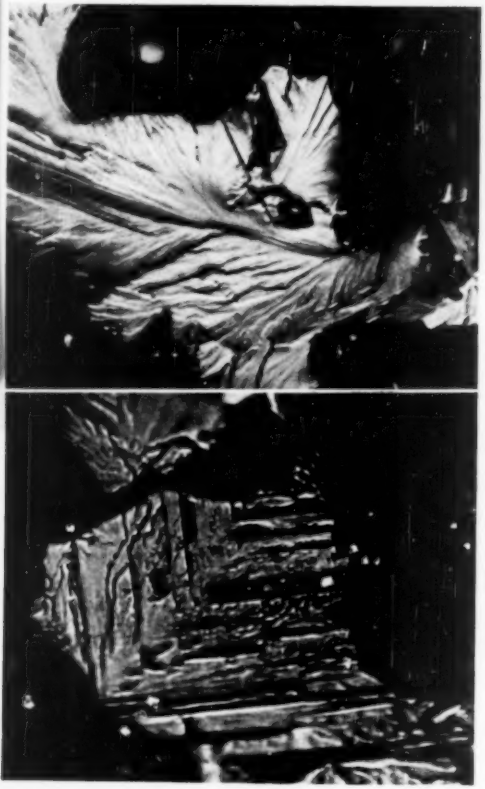


Fig. 15 Further facets of Steel E showing flatness, expansiveness and block structure. 1250 ×; reduced by 1/2 in reproduction

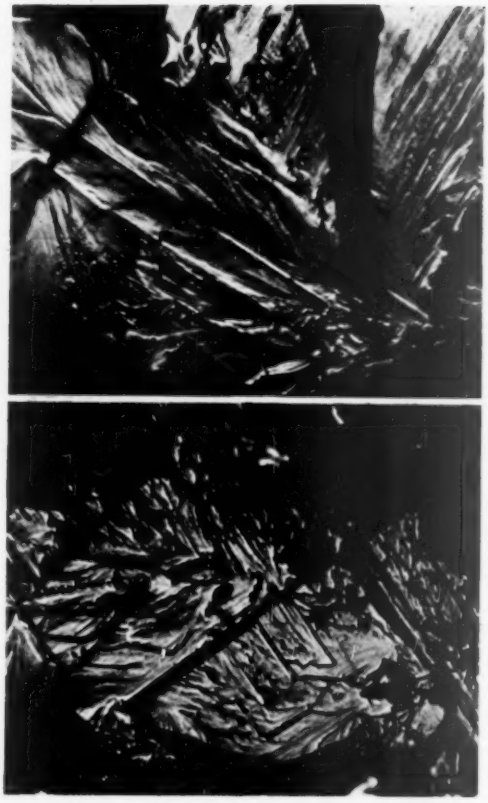


Fig. 16 Facets of Steel H, showing undesirable cleavage characteristics which are apparently compensated by a strengthening factor within the matrix attributable to the high aluminum content. Above, 1250 ×; below, 800 ×; reduced by 1/2 in reproduction

factor. The proof of this assumption would lie in preparing dehydrogenized steel—something that has never been done.

Only the 12-in. plate tests in Table 1 fail to designate Steel A as inferior to D in the as-rolled condition. Fractographically, Fig. 12 discloses a pattern very similar to that in Fig. 10, such that there is some difficulty in drawing a distinction on the basis of pattern alone. However, the facets of A are larger, which concerns an influence of Factor III. They are also possibly flatter. Crystallographic markings are present to about the same extent. The conclusion would place Steel A slightly inferior to Steel DR, which is a fair compromise of the divergent results in the table. However, the slight additions of alloying elements in Steel D must also be taken into consideration as a possible augmentation of toughness according to Factor I. Other components also differ substantially in the analyses.

Steel C. Marked flatness accompanied by block-structure in the pattern of Steel C (see Fig. 13) makes the conclusion unanimous with the results in Table 1

that this steel is inferior to any yet observed. Block structure, of course, is a delineation of {001} cleavage; and patterns in which this is prominent can immediately be classed as indicating a preference of cleavage to slip, whether or not hydrogen is an active factor as proposed in discussing Steel DN.

Steel E. Of all the steels in this first series, Steel E provides the most certain indications of easy cleavage and general lack of toughness. Figures 14 and 15 reveal expansive flat facets, frequently containing evidence of block structure. The conclusion to be drawn is unanimous with the criteria in Table 1 that this rimmed steel is the least desirable on the basis of cleavage characteristics.

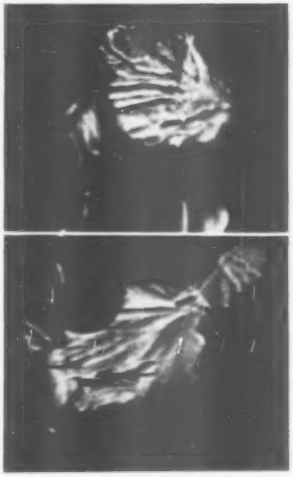


Fig. 17 Facets of Steel N, showing flatness comparable to Steel DN in Fig. 11, but apparently compensated by the strengthening effects of small grain size and a nickel content of several per cent. 1500 ×; reduced by 1/3 in reproduction

Steel H. Although Steel H cannot be classified as an alloy steel, its fractography plainly requires that it be separated on some basis from the eight preceding steels. Some factor at least resembling Factor I must be taken into consideration. This can perhaps be allowed in view of the fact that the residual aluminum content is several times larger than in the other steels (Table 1). Apparently aluminum is a strong factor in improving the toughness.

Mechanical tests listed in Table 1 would classify Steel H perhaps with Steel Q, which was the best in the series just reviewed; but the fractographs (Fig. 16) disclose facets seemingly as objectionable as those in Steel E on all counts of flatness, expansiveness and even presence of block-structure.

Accordingly, we have here a striking demonstration of a limitation of the fractographic method as a direct approach without consideration of other factors. As stated before, effects of various treatments upon any given steel can be followed simply and dependably by cleavage pattern; but two matrices differing in constitution cannot be so compared. For a complete evaluation, at least the three prominent factors given in the introduction must be considered.

Steel N. A second example of the importance of Factor I, now in combination with Factor III, stands in the pattern of Steel N, shown in Fig. 17. Here the facets are actually comparable to those of DN (Fig. 11) in flatness, yet the steel is unanimously proved by

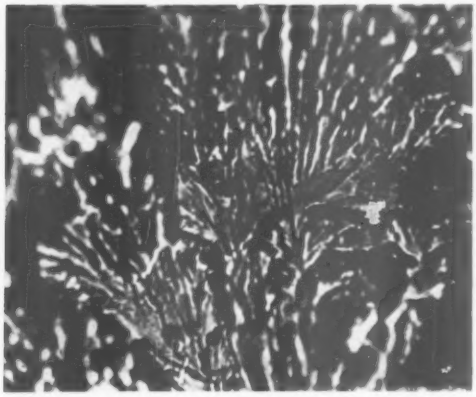


Fig. 18 Pattern of Steel Q after reheating to 550° C. for 1/3 hr. and cooling in air. The "coral" pattern of toughness persists, though perhaps evidencing some increase in flatness. 1500 ×; reduced by 1/3 in reproduction

Fig. 19. Patterns of Steel Q after heating at 950° C. for 1/3 hr. and furnace-cooling. All evidence of toughness has now vanished, the flat and crystallographic facets indicating extremely poor cleavage characteristics. 1500 ×; Reduced by 1/3 in reproduction

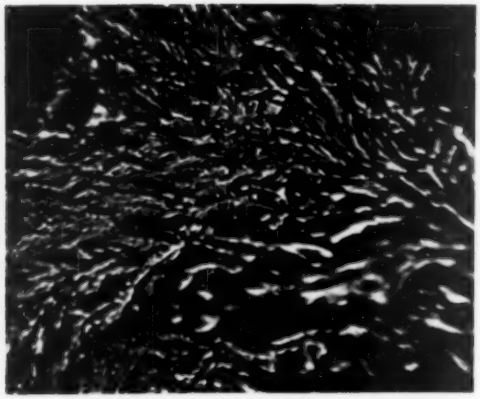


Fig. 20 Pattern of Steel E after reheating to 950° C. and quenching in oil. The flat, crystallographic facets of the as-rolled steel have been converted essentially to the "coral" pattern characterizing the quenched and drawn Q steel in Figs. 6 and 7. 1500 ×; reduced by 1/3 in reproduction

mechanical testing to exceed all steels listed in Table 1 on the basis of toughness and low slip-transition temperature.

As for Factor I, this N steel contains several per cent of nickel, which apparently so increases atomic cohesion that the material is lifted well out of the class containing Steel D. Next, the grain size of Steel N is finer than that of Steel E, for example, by an area factor of six, which will certainly greatly increase Factor III in the direction of improving the resistance to cleavage, and hence general toughness.

Some Observations on Heat Treatment

Although these observations raise a great number of questions concerning the variability of the cleavage pattern with the many factors known to influence the mechanical properties of steel, it is sufficient for this preliminary study to close with a few tests on the two end-members of the group of eight mild steels—steels Q and E.

Referring back to Figs. 6 and 7, one sees the pattern of Steel Q in the quenched and drawn condition. Reheating this steel to 550° C. for 1/2 hr. and cooling it in air provided the patterns shown in Fig. 18. The coral terrain of toughness persists, though there is some evidence of increased flatness.

Reheating Steel Q to 950° C. for 1/2 hr. followed by a furnace-cool, resulted in the patterns of Fig. 19. All vestiges of a coral pattern have vanished. In fact, the terrain is so flat and crystallographic, even containing evidence of block structure, that one is allowed to estimate this to be an inherently poor steel which has been raised to its position of relative excellence in the table only through the quenching operation.

Conversely, Steel E held at 950° C. for 1/2 hr. and quenched in oil provided the patterns shown in Fig. 20. But little distinction can be made between these and the original patterns for Steel Q in the previous Figs. 6 and 7. The flat facets in the as-rolled steel have been converted into rough, noncrystallographic facets denoting much improved cleavage characteristics.

CONCLUSION

From this preliminary study of the fractographic structures in standard ship-plate specimens, the following tentative conclusions can be drawn:

1. At least three fundamental factors are prominent in controlling the cleavage characteristics, and hence probably toughness, of the steels under consideration: (I) atomic cohesion, (II) transgranular traverse, and (III) intergranular traverse.

2. Fractography is directly applicable to Factor II, also Factor III, but not as yet to Factor I.

3. For a given steel, or within a series of steels of closely similar composition, the cleavage patterns accurately and readily disclose the toughness of the material in excellent agreement with mechanical tests on 12-in. plate, 72-in. plate, and Charpy impact specimens.

4. Toughness in such a series is coincident with a "coral" type pattern showing distortion, rough traverse and an absence of crystallographic markings.

5. Decreased toughness is coincident with an onset of smoothness, flatness and crystallographic registrations.

6. A condition of minimum toughness is characterized by expansive, flat facets highly marked with crystallographic registrations to a point of evidencing block structure where tiny crystallographic units have pulled away along secondary cleavages.

7. Heat treatment is a principal factor in establishing these patterns, hardening producing a pattern of toughness perhaps characterizing martensite, and annealing producing a pattern of nontoughness related to easy cleavage through undistorted ferrite grains.

8. Normalizing seems to decrease the toughness to an intermediate degree consistent with its position between hardening and annealing, but in some steels this limited effect seems counteracted by an opposing factor which is believed to be related to hydrogen in the steel.

9. Alloying elements, Factor I, strongly affect toughness without an influence on the pattern which is yet recognizable.

10. Aluminum seems particularly important as an alloying element, small quantities markedly increasing toughness.

11. Hydrogen as an effective remanent impurity in the steels is indicated by the block structure in inferior specimens, the contrasted response of steels B and D to normalizing, the fact that slip-transition temperatures are higher for thicker plate from any one heat,[13] and several anomalous divergences in slip-transition determinations by different investigators handling the steels after elapsed periods of time. Dehydrogenized steel has never been applied to ship plate; and the authors believe that it is of the utmost urgency to the ship-plate

problem that the effects and the control of this powerful and as yet uncontrolled constituent be studied with respect to slip-transition phenomena.

ACKNOWLEDGMENT

To the Office of Naval Research all acknowledgment is due for supporting the fundamental research program on Fractography from which the present paper stems as a special study and particularly to I. R. Kramer, Mechanics and Materials Branch, ONR, whose close personal interest has greatly aided prosecution of the research.

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Steel Properties Related to Welded Performance

The individual influence of each of the various common alloying elements upon the capacity of the joint to absorb work under concentrated stresses, at both normal and subzero temperatures, has been evaluated relative to that of carbon at normal temperature

by J. Heuschkel

Abstract

Total carbon and alloy content is shown to be the basic variable influencing postwelded deformation and energy absorption capacities of welded tee-joints under concentrated stress at both normal and subzero temperatures. This conclusion is based upon an analysis of the results from previously reported tests which were prepared and bent under similar conditions. The specific conclusions are limited to steel plates $^1/_2$ in. thick. Rolling conditions provide an independent variable which influences welded performance through its effect upon prewelded ultimate strength. Maximum postwelding hardness is influenced, for a given composition, by variations in the quench rates which result from variations in welding procedure or conditions. Shape of the weld alters the stress concentration at the weld edge. All of these secondary variables are pertinent factors which further affect the results at each test temperature for any one analysis.

For each family composition and bending temperature, optimum prewelded yield and ultimate strengths and pre- and postwelding hardness ranges exist. The limits of these ranges for optimum welded performance are different at normal and at subzero temperatures and are provided for nine steel composition types. The individual influence of each of the various common alloying elements upon the capacity of the joint to absorb work under concentrated stresses, at both normal and subzero temperatures, has been evaluated relative to that of carbon at normal temperature. A composite relation between total analysis and welded performance under both normal and subzero test conditions is presented.

For the same welded joint energy absorption, higher tensile yield strengths are obtainable with low alloy steels than with plain carbon steels. The lower alloy additions, for any composition family, provided the better welded joint characteristics, under concentrated bending stresses. Too high analyses, strengths and hardnesses cause brittle fractures and must be avoided for best results for all compositions. Too low analyses cause inadequate plate strength. Optimum compositions are shown to exist for each composition type.

J. Heuschkel is a Research Engineer at the Westinghouse Research Labs., East Pittsburgh, Pa.

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INTRODUCTION

MANY important welded structures, including ships and bridges, require a combination of adequate strength in the unwelded portions of the component members with an assured capacity of the welded joints to withstand concentrated stresses, often under shock conditions and commonly at subzero temperatures. Fabrication by welding involves three essential and distinctly different steps; first, the formation of the weld metal, second, the solidification of the metal without cracking and third, the production of

joints having adequate properties. Success in the first two steps does not necessarily assure achievement of the third. For example, the welder in the act of welding ordinarily cannot individually evaluate the three, provided that the welding process is being successfully carried out. An x-ray sound joint is not necessarily strong or ductile.

A welded structure may fail by excessive plastic deformation or by fracture at the welded joint. Several factors influence the capacity of sound uncracked welded joints to deform under conditions of concentrated stress without failure. Among these are the composition of the base metal, the rolling conditions under which the base metal was produced, the resulting prewelded tensile strength of the base metal, the magnitude of the applied stress, the welding procedure employed and the temperature of the joint at the time the stress is applied. Other factors may be the plate grain size, deoxidization practice, amount and distribution of inclusions, the resultant microstructure and the shape of the weld edge notch.

It is the purpose of this presentation to establish the interrelationships between the optimum plate yield and tensile strengths, and pre- and postwelded hardnesses and initial plate compositions for nine composition type families at both normal and subzero temperatures. The derivation of these interrelationships and the determination of the optimum ranges of plate properties and joint performance are based upon a previous paper in which data were presented on the behavior of welded tee-joint bend specimens in $^1/_2$-in. thick plate; all welding and testing being done with a standardized operational and dimensional procedure.[1]

Resistance to plastic deformation is measured by the tensile test and is readily increased by an increase in carbon or alloy content. Resistance to fracture at the welded joint under concentrated stress is not necessarily continuously increased by increases in tensile strength of the plate. The proof of this will be demonstrated. A measure of resistance to fracture at the welded joint under conditions of concentrated stress is provided by bending an unflushed joint with the welded irregularity on the tension side. Several different types of specimens could be used for this purpose. The tee-joint bend specimen meets the described conditions, and it is a common structural joint. Fracture strength of the plate at the weld edge in such joints may be lowered both by metallurgical changes at the weld edge and by severe stress concentrations produced by the weld contour. Fracture of such joints may occur after any extent of deformation or it may not occur at all, depending upon the existing conditions.

Under bending conditions which do not produce early failure by fracture in such a joint, the maximum bending load resisted tends to relate closely to the prewelded tensile strength of the steel and is, under those conditions, independent of composition. When failure by fracture occurs, the total energy absorbed also relates to the prewelded tensile strength for any one family composition. These energy values first rise and then fall with progressively increasing strengths, which means that there is an optimum plate strength range for best welded joint performance.

There is a definite relation between the prewelded yield and ultimate strengths for hot-rolled plates of any one family composition and rolling practice. The same general relations therefore exist between energy absorbed and yield strength as are obtained for ultimate strength. There is also an approximate relation between the prewelded plate hardness and ultimate strength. Again the same general relation between prewelded plate hardness and absorbed joint energy exists for any one composition type.

Welding results in hardening of the ferritic steels adjacent to the weld zone. For any one condition of thermal instability, the maximum resulting hardness is of an order which can be related to the prewelded hardness for any one composition type. Therefore, maximum hardness becomes a fourth property which may be related directly to the energy absorbed by the specimens. It will be shown that the same type of interrelationship pattern exists between each of the four strength and hardness variables and the welded performance, for all reported compositions, but that the specific values of strength and hardness corresponding to the same welded performance vary with composition type.

For any one composition type all four of the relatable values, that is, the prewelded plate yield and ultimate strengths and the prewelded and maximum postwelded plate hardness, also relate to and continuously increase with increased carbon and total weighted alloy contents, for a fixed rolling condition. Therefore it is the composition which is the primary variable in producing changes in the welded performance of hot-rolled plates. The welded performance first rises and then falls with increases in total content of hardening agents as the resultant plate strength and hardness continuously rises and there is accordingly an optimum composition corresponding to the optimum physcial properties for the best welded performance. Each incremental amount of every alloying element studied contributes toward making up the total composition which can be expressed as an equivalent carbon content. Having established the relation between equivalent carbon content and welded performance it becomes possible to deal with variations in composition based upon accumulative experience.

In structural design high yield strength is the property most widely sought. Since welded performance is related to both ultimate and yield strengths, and the yield-ultimate ratios are functions of composition for hot-rolled plates, the steels with the highest yield to ultimate strength ratios are the more suitable for withstanding high static test loads and for absorbing energy under dynamic conditions without failure, provided the strengths and compositions are properly adjusted. For best results both the strength and total composition must be sufficiently low that premature brittle failure does not occur in the hardened heat-affected metal at the weld edge notch under the high imposed stresses,

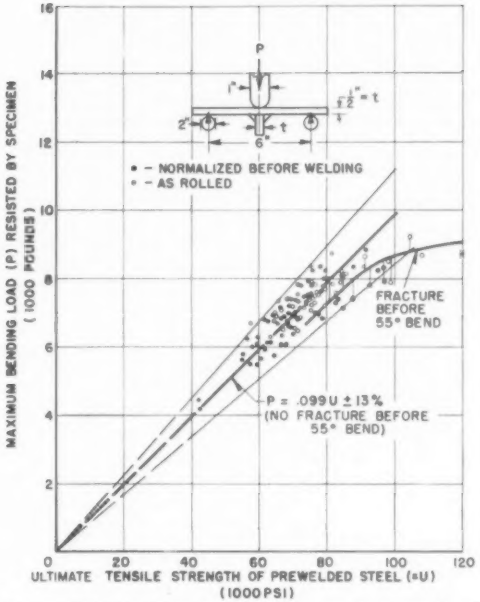

MAXIMUM BENDING LOAD (P) RESISTED BY SPECIMEN (1000 POUNDS)
ULTIMATE TENSILE STRENGTH OF PREWELDED STEEL (=U) (1000 PSI)
P
2"
6"
t
• – NORMALIZED BEFORE WELDING
◦ – AS ROLLED
FRACTURE BEFORE 55° BEND
P = .099U ± 13%
(NO FRACTURE BEFORE 55° BEND)

Fig. 1 Relation between ultimate tensile strength of steel and maximum bending load at +70° F. (all compositions)

but the strengths and compositions must not be too low.

STATEMENT OF PROBLEM

Having secured a mass of data from tests conducted under controlled conditions[1] one is faced with the problem of attempting to determine the law of variation of the response of the welded joints to the imposed conditions. In general it was impossible to detect operational differences during the welding process on the different steels which, before welding, ranged from relatively low to high in both strength and hardness as the chemical analysis was varied. Since, after welding, the specimens ranged from ductile to brittle the problem is to determine whether a describable trend exists throughout the reported results. The definition of such a trend should be valuable in selecting steels for similar conditions of stress and service temperature after welding.

TEST METHOD

For the reader's convenience a condensed description of the test method previously reported[1] is repeated: Commercially hot-rolled ½-in. thick steel plates were secured. Check analyses of the steels and their tensile properties at normal temperatures for two prewelded conditions, as-rolled and normalized, were reported. Generally speaking, identical 24- x 12-in. pieces in both the as-rolled and normalized (1675° F. and air cool) conditions were single-pass fillet welded with E6010 electrodes in a room at normal temperature, both with and without a plate precool to −20° F., to form double fillet welded tee-joints 24 in. long. The welds were made transverse to the direction of rolling except as specifically noted. From each of the four joints thus produced from each plate, six 1¼-in. wide bend specimens of full plate thickness were prepared from the center of the joint; three for test in air at normal room temperature and three at −20° F. in a refrigerated bath. The specimens were tested at a speed of 3 in./minute between 2 in. diameter rollers spaced 6 in. between centers with the fillet welded side of the specimen in tension,[2] as sketched in the upper part of Fig. 1. All specimens were tested in the as-welded condition; no postwelding heat treatment was employed in the reported data. The total angle of bend at failure or jig capacity, the maximum load resisted and the type of failure were reported.

In accordance with a testing and evaluation refinement developed by the author, load-deflection diagrams were secured[3] and from the areas under those diagrams, as shown in the lower part of Fig. 2, the energy of rupture was obtained. The average energy absorbed for each set of these specimens, in inch-pounds, to deflect the specimen to failure or to the test jig capacity of 130° was related to the average value (13,200 in.-lb.) obtained from one selected set of unfractured tests[1] on a 0.20% carbon, 30,800 psi. yield strength, 60,900 psi. ultimate strength plain carbon steel welded and tested at normal temperature to provide a specific performance rating. In all cases the actual absorbed energy in inch-pounds is equal to this rating or specific performance multiplied by 132.

TREATMENT OF DATA

The available data are now treated to bring out progressively the influence of rolling direction and conditions, prewelded physical properties, maximum postwelded hardness, temperature of test, chemical

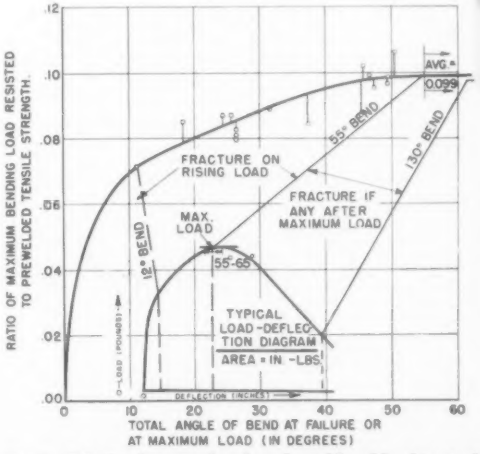


Fig. 2 Relation between bend angle and bend load to steel strength ratios at +70° F. (all compositions)

composition of plate and the relative influence of the individual alloying elements.

Since the first 7 in. of each 24-in. test joint was discarded, and during the deposition of this portion of the welds in the precooled joints the plate warmed up a substantial amount, it is logical that little over-all difference was found between the results from the precooled and nonprecooled joints, after welding in a room at normal atmospheric temperatures. The first condition generally provided the lowest ductility values and highest hardnesses, but the differences were small and the results from both conditions were averaged for the purpose of this study. Each plotted performance point therefore becomes the general average obtained from six welded joint specimens.

RESISTED LOADS

For the test proportions investigated, fractures at total angular deformations less than 55° occurred on a rising load and resulted from inadequate notch ductility; those between 55 and 65° occurred at maximum load; and those occurring after reaching 65° occurred after the specimen has withstood the maximum load. The last group occurred on a falling load with progressively increasing local strain which was then commonly concentrated at some distance from the weld edge. When fracture resulted before a 55° total angle of bend, it usually occurred at a lower load than would have been obtained had a larger angular deformation been secured. These relations are clarified by the diagram in Fig. 2.

T-bend strength, expressed as maximum pounds resisted, increased consistently with prewelded ultimate strength and was wholly independent of plate composition, so long as fracture did not occur before a 55° angle of bend. Ductility is measured in the T-bend test by deformation to fracture. Linear deformation and angular distortion are closely related. Since notch ductility limits T-bend strength, it is statically as important as strength up to the point of assuring that maximum potential maximum load will be resisted.

Both the as-rolled and normalized values for maximum obtained loads in pounds for the +70° F. bend tests are plotted in Fig. 1 against the corresponding ultimate strength of the prewelded steel, for those specimens which did not start to fail before reaching a 55° angle of bend. This grouping includes all specimens which reached peak load before failure, if any, as shown in Fig. 2, and is thus descriptive of a "ductile" type of performance. The average maximum load resisted for those specimens is a linear function of the prewelded ultimate tensile strength and may be expressed as: Eq. 1..... $P = 0.099U \pm 13\%$ where P is the maximum load in pounds and U is the ultimate strength of the prewelded steel in pounds per square inch.

BASIS FOR WELDED PERFORMANCE RATINGS

Since the load resisted, for ductile performance, tends to relate to ultimate strength of the prewelded steel, from mechanical considerations the actual imposed stress at the extreme fiber, including the weld edges, must also increase with prewelded strength and must approach that of the strength of the prewelded steel at peak load. The local notch stresses are not actually measured in a bend test. For a given composition for the fixed loading and dimensional condition used in these tests, a stronger steel resulting from cold finishing or higher carbon and alloy contents is subjected to the higher notch stress since the load is shown to be higher. Thus while identical bending conditions are employed the imposed stress conditions are not identical. The high strength steels are usually capable of resisting the higher maximum static loads but the joints may be less ductile when the stress concentration increased sufficiently with prewelded strength to cause early fracture.

Joint ductility not only limits the maximum load resisted, it also controls the amount of energy absorbed under dynamic loading. Since joint ductility and static strength are of equal importance, from the viewpoint of energy absorption in bending, the area under the load deflection curve or the energy absorbed is taken as a measure of welded joint performance. Capacities of welded joints to resist both static and dynamic loads

Table 1—Influence of Rolling Direction Upon Energy Absorbed in Welded Tee-Joints from As-Rolled Plates

Steel analysis, %						Energy absorbed at +70° F. in longitudinal specimens, In.-lb.	Energy absorbed as ratio of corresponding +70° F. Longitudinal Specimens		
C	Mn	P	S	Si	Steelmaking practice		Longitudinal Test at −20° F.	Transverse Test at +70° F.	Transverse Test at −20° F.
0.24	0.45	0.015	0.025	0.004	Mechanically capped	16,200	1.06	0.76	0.78
0.25	0.46	0.024	0.026	0.004	Mechanically capped	16,100	0.83	0.58	0.47
0.25	0.47	0.021	0.025	0.008	Semikilled	15,400	0.81	0.64	0.47
0.25	0.43	0.011	0.023	0.012	Al killed	15,500	0.55	0.72	0.69
0.25	0.51	0.025	0.030	0.020	Al killed	15,700	0.59	0.50	0.43
0.25	0.43	0.011	0.027	0.05	Semikilled	15,700	0.48	0.33	0.26
0.22	0.45	0.014	0.030	0.12	Silicon killed	16,400	0.87	0.31	0.34
0.27	0.46	0.023	0.029	0.15	Silicon killed	15,000	0.60	0.36	0.28
Av. 0.25	0.46	0.018	0.027			15,750	Varies with silicon content		

Table 2—Influence of Normalizing Before Welding Upon Steel Properties and Energy Absorbed in Welded Tee-Joints

Steel composition type	No. of heats	Per cent of times yield point decreased*	Per cent of times ultimate strength decreased*	Yield-ultimate ratio, Av. As-rolled	Yield-ultimate ratio, Av. Normalized	Per cent of times welded performance increased* +70° F.	Per cent of times welded performance increased* −20° F.
Carbon	25	77.0	84.6	0.593	0.580	50.0†	57.0†
C-Mn	7	50.0	66.7	0.611	0.628	85.7	57.2
P-Cu-Ni	4	100.0	100.0	0.643	0.632	75.0	100.0
Si-Mn	4	50.0	75.0	0.610	0.628	75.0	75.0
Si-Cu-Ni	1	100.0	100.0	0.730	0.727	00.0	100.0
Ni	2	100.0	100.0	0.675	0.680	50.0	00.0
Cr-Mo	3	50.0	100.0	0.749	0.681	50.0	100.0
Mn-Mo	4	100.0	100.0	0.659	0.607	100.0	00.0
Mn-V	3	100.0	100.0	0.706	0.731	50.0	100.0
Mn-Ti	20	90.0	95.0	0.704	0.712	46.2†	83.5†
Total	73	...	...	...	...	...	...
Overall	..	78.2	89.0	...	...	58.0	61.9

* Per cent of times comparisons are available.
† Values influenced by fact that for conditions of no failure a reduction in prewelded strength is accompanied by a reduction in energy absorbed by welded joint. This results from a decrease in the load resisted by the specimen.

are factors which enter into adequacy of welded performance. The energy absorbed when related to that absorbed by a common low-carbon structural steel, welded and tested at room temperature, provides a basis for evaluating specific welded performance with respect to that of a proved standard.

INFLUENCE OF ROLLING CONDITIONS

(*a*) *Directional Effects*

Welded performance is related to grain orientation. This is shown repeatedly by the lowered capacity of transverse specimens to withstand angular deformations and to absorb energy as compared to that withstood by the corresponding longitudinal specimens. This is summarized by the data in Table 1 for 8 heats of carbon steels in the as-rolled condition. In general, bending across the grain (transversely) provides lesser values than those obtained when bending with the grain (longitudinally). These observations indicate the necessity of considering the transverse bending characteristics of welded joints.

(*b*) *Steel Making Practice*

Essentially, the steels in Table 1 vary only with respect to manufacturing practice. That variation results in different silicon contents. The composition-strength balance of these steels was such that all longitudinal specimens were of the high performance level when tested at +70° F. As different steelmaking practices resulted in higher residual silicon contents, somewhat lesser capacities to absorb energy were available at subzero temperatures on the longitudinal specimens, but the effect was very marked for the transverse specimens at both test temperatures.

Had either a higher or a lower composition been available for comparison with the corresponding strength changes, somewhat different magnitudes of influence would have been expected from the direction of rolling and also from variations in steelmaking practice; that is, at both lower and higher composition levels lesser effects would have been found. This is further clarified later under the treatment of the influence of silicon upon welded performance. All the following conclusions now apply specifically to results obtained from longitudinal specimens.

(*c*) *Finishing Temperatures*

The ultimate tensile strength, the yield strength and the yield-ultimate strength ratio are all increased for a given composition by the application of cold work. The influence of such finishing treatments is removed by subsequent normalization; that is, heating above the

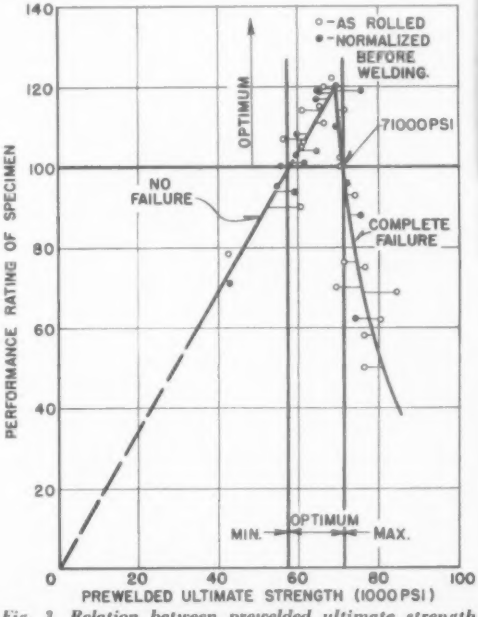


Fig. 3 Relation between prewelded ultimate strength and welded specimen performance (+70° F.; carbon steels)

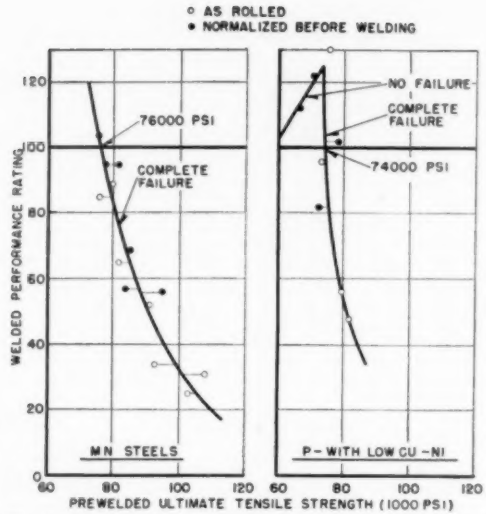


Fig. 4 Relations between prewelded tensile strength and welded performance at +70° F. for Mn and P + low CU-Ni steels

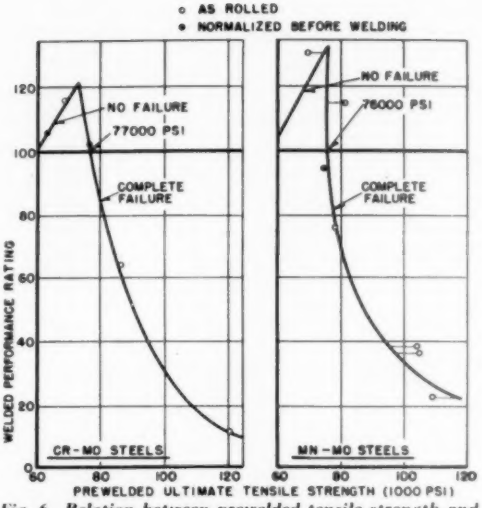


Fig. 6 Relation between prewelded tensile strength and welded performance at +70° F. for Cr-Mo and Mn-Mo steels

critical temperature and air cooling. While the physical properties of some of the individual tested heats were influenced materially by rolling conditions, on the whole the yield-ultimate strength ratios were little influenced by this treatment. This is summarized by the data in Table 2 which shows that prewelding normalization of commercially hot-rolled plates generally reduces both the prewelded yield and ultimate strengths. Also for those as-rolled joints with brittle fractures it usually produces an increase in the energy absorbed in accord with a trend to be described in detail under physical properties.

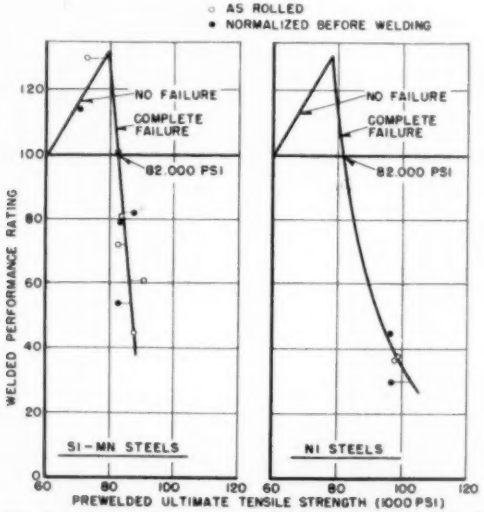


Fig. 5 Relations between prewelded tensile strength and welded performance at +70° F. for Si-Mn and Ni steels

INFLUENCE OF PREWELDED PHYSICAL PROPERTIES

Tensile Strength

The relations between prewelded ultimate tensile strength of the steels and the welded performance at

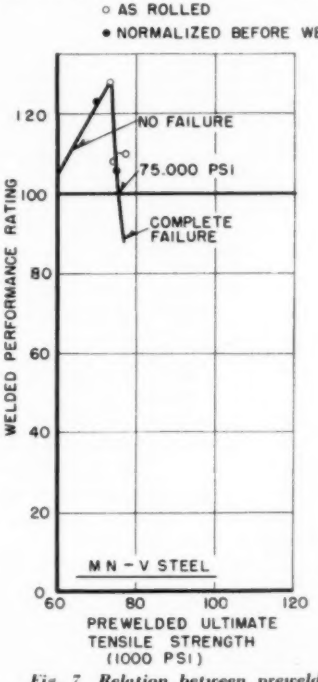


Fig. 7 Relation between prewelded tensile strength and welded performance at +70° F. for Mn-V steel

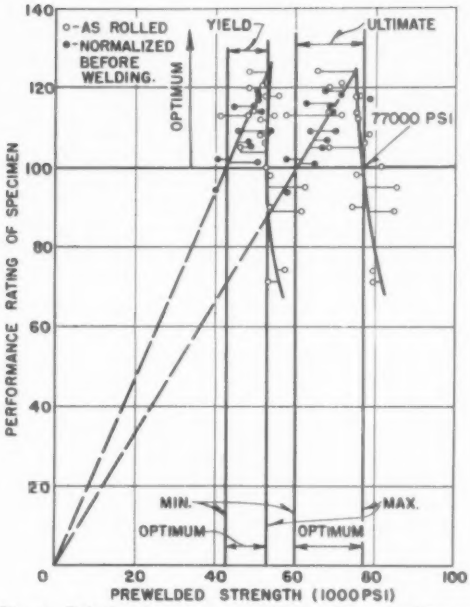


Fig. 8 Relation between prewelded yield and ultimate strengths and welded specimen performance at +70° F. for Mn-Ti steels

normal temperatures for both the as-rolled and the normalized conditions, are shown in Fig. 3 to 8, inclusive. The absorbed energy first gradually increases, without failure of the specimen, as the tensile strength of the steel increases up to some maximum strength which varies with composition, and then fracture occurs at peak load. With conditions which produce fracture, further increases in tensile strength result in rapidly decreasing amounts of absorbed energy. The general pattern is the same for all compositions. From these graphs it is possible to define the average upper and lower strength intercepts which result in optimum energy absorption. For the purposes of the present discussion these limits have been taken for a minimum performance of 100 at +70° F. Other limits could be chosen. Based upon the magnitudes of the strength intercepts it now becomes possible to rate the various steel composition families, based upon their capacity to absorb energy under concentrated stress conditions after welding and at the same time provide maximum tensile strength. These relative listings are shown in Table 3, arranged in descending order of maximum corresponding yield strength.

The curves, Figs. 3 to 8, further clarify the role of prewelded normalization. For example, with a high as-rolled plate strength the performance may be low, but when normalization decreases the prewelded tensile strength, the performance is generally increased. If, with medium plate strengths, fracture of the as-rolled bend specimen occurred after fairly high energy absorption values, the prewelding normalization treatment either further increased the energy absorbed before fracture by reducing the tensile strength, or it caused the stress to be so reduced that no fracture occurs. A third effect is noted for conditions wherein no fracture occurred with the as-rolled plates. In this case, if normalization further reduced the tensile strength, the energy absorption, and therefore the performance ratings were further reduced as a consequence of the reductions in material strength.

Prewelding normalization of the plates thus influences welded performance primarliy through its effect upon the tensile properties, Table 2. The welded performance of prewelded normalized plates is generally superior to that of as-rolled plates for the higher compositions and inferior for the lesser compositions, reflecting the shifting influence of plate strength upon welded performance.

The rising portion of the performance-strength curves, in Figs. 3 to 8, projects back to the zero or origin point and this entire lower portion is essentially independent of analyses. The high side strength and minimum welded performance intercept varies slightly with composition family type and thus the maximum permissible strength range for a given minimum welded performance will vary somewhat with composition. The maximum obtainable welded performance, or energy absorption for alloy steel, however, is but little better than that of plain carbon steels; the dependable superiority being on the order of 13 : 12, or even less.

At normal temperatures in each composition family

Table 3—Ranges of +70° F. Prewelded Physical Properties and Maximum Postwelded Hardness for a Minimum Welded Performance of 100 at +70° F. Under Test Conditions

		Plate tensile strength, psi.					Hardness (DPH)			
		Yield		Ultimate		Average value of yield to ultimate ratio	Average prewelded		Max. in heat affected zone	
Relative order	Alloy type	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.
1	Nickel	42,000	57,000	60,000	82,000	0.701	130	177	183	250
2	Mn-V	44,000	54,000	60,000	75,000	0.727	128	160	179	224
3	Mn-Ti	42,000	54,000	60,000	77,000	0.708	125	160	154	197
4	Cr-Mo	40,000	51,000	60,000	77,000	0.660	134	172	193	248
5	Mn-Si	37,000	51,000	60,000	82,000	0.619	125	171	172	236
6	Mn-Mo	38,000	48,000	60,000	76,000	0.633	136	165	185	224
7	P + low Cu-Ni	38,000	47,000	60,000	74,000	0.638	132	163	203	251
8	C-Mn (Mn > 0.75)	37,000	47,000	60,000	76,000	0.620	120	152	186	236
9	Carbon (Mn < 0.75)	34,000	42,000	58,000	71,000	0.588	120	147	175	215

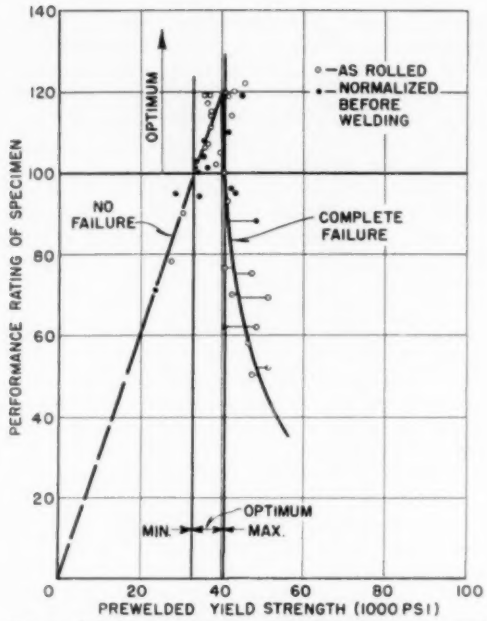


Fig. 9 Relation between prewelded yield strength and welded specimen performance (+70° F.; carbon steels)

of steels, maximum welded performance is obtained when plate ultimate strength exceeds 58,000 to 60,000 psi. but is less than 71,000 to 82,000 psi., Table 3. The common occurrence of the 60,000 psi. minimum strength in Table 3 relates to the standard of comparison selected; that is, it was a 60,000 psi. steel.

Yield Strength

Most structures are designed on yield strength. The relationships between obtainable yield strength and welded performance were therefore determined. This could be done in each case directly, as shown for the manganese-titanium and carbon steel data in Figs. 8 and 9. However, a simple means was to apply the obtained average yield-ultimate strength ratios, as listed in Table 3, to the optimum ultimate strength values obtained from Figs. 3 to 8. This procedure was made possible by the fact that for each composition family there is a fairly definite yield to ultimate strength ratio. This ratio is increased by the additions in alloy content. It may also be increased by cold work.

An optimum range of yield strength is also obtained for best welded performance for each composition family. The welded performance vs. prewelded yield strength relationship is of the same pattern as for the prewelded tensile strength except for different numerical values, and the magnitude of the intercepts are substantially different for the alloy steels as contrasted with the plain carbon steels. Average minimum plate yield strength for maximum welded performance increased from 34,000 psi. for the low manganese carbon steels to 42,000 psi. for Mn-V, Mn-Ti and nickel steels. The upper limit of the prewelded plate yield strength range for maximum welded performance is increased more by alloy content, over that obtainable from carbon steels, namely from 42,000 to 55,000 psi.

The gain in yield strength of the alloy steels over that from the plain carbon steels for a given welded performance was obtained with only minor increases in hardness of the heat-affected zone. Since the welded performance related closely to prewelded ultimate strength the compositions which provide the higher yield to ultimate ratios are generally the more desirable.

Prewelded Hardness

The relations between prewelded hardness and welded performance follow the same pattern as the prewelded strength to welded performance patterns shown in Figs. 3 to 8, since there is a close approximate relationship between prewelded plate strength and prewelded plate hardness for each composition type. Based upon these values, the optimum ranges for prewelded plate hardness are also given in Table 3. These derivations are based upon the reported average strength-hardness ratios of:

Steel composition type	*Average prewelded strength-hardness ratios: (= UTS in psi./DPH)*
Mn-Mo	442
Cr-Mo	448
P + low Cu-Ni	454
Nickel	463
Mn-V	470
Mn-Ti	480
Si-Mn	481
Carbon	482
C-Mn	501

The same general relations therefore exist between prewelded plate hardness and final welded performance as were shown to exist for variations in the prewelded plate tensile strength. Prewelded plate hardness is a function of both composition and rolling conditions.

INFLUENCE OF HARDNESS AFTER WELDING

The average limits for maximum hardness after welding could be determined by calculating the general increase in maximum over prewelded hardness, expressed as a ratio, and multiplying these values by the prewelded hardness limits as listed in Table 3. The limits for maximum hardness in the heat-affected zone determined by this method are also shown in Table 3. The average reported increases in hardness were:

Steel composition type	*Average maximum postwelded hardness to prewelded hardness ratio*
Mn-Ti	1.23
Mn-Mo	1.36
Si-Mn	1.38
Nickel	1.41
Cr-Mo	1.44
Carbon	1.46
P + low Cu-Ni	1.54
C-Mn	1.55

On the higher analyses the relative increase in hardness was greater than for the low compositions. Maximum permissible hardness varies with composition type for a given welded performance and the specification of a common general value for maximum hardness for all compositions is not practical.

A typical direct plot of welded performance vs. maximum hardness in the heat-affected zone for the carbon steels is shown in Fig. 10 to demonstrate that the two methods of approach give about the same results. With a single hardness traverse on one specimen it is possible that the peak hardness was not always secured, hence more scatter is obtained.

For other welding conditions or for different plate thicknesses, using the test conditions, either greater or lesser hardness values may be obtained, depending upon quench conditions. For all cases the final maximum hardness is essentially independent of rolling conditions but not necessarily of prior plate thermal treatment. The same general type of relations exists between maximum plate hardness after welding and welded performance as were found to exist for prewelded plate tensile strength; that is, welded performance gradually rises

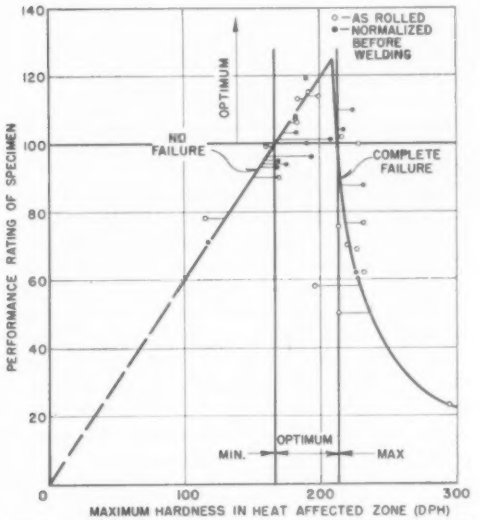


Fig. 10 Relation between maximum hardness and welded specimen performance (+70° F.; carbon steels)

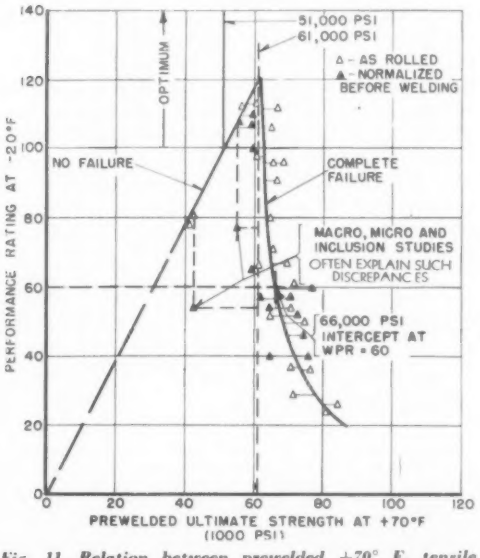

PERFORMANCE RATING AT -20°F
PREWELDED ULTIMATE STRENGTH AT +70°F (1000 PSI)
51,000 PSI
61,000 PSI
Δ - AS ROLLED
▲ - NORMALIZED BEFORE WELDING
OPTIMUM
NO FAILURE
COMPLETE FAILURE
MACRO, MICRO AND INCLUSION STUDIES OFTEN EXPLAIN SUCH DISCREPANCIES
66,000 PSI INTERCEPT AT WPR = 60

Fig. 11 Relation between prewelded +70° F. tensile strength and low temperature welded performance of plain carbon steel

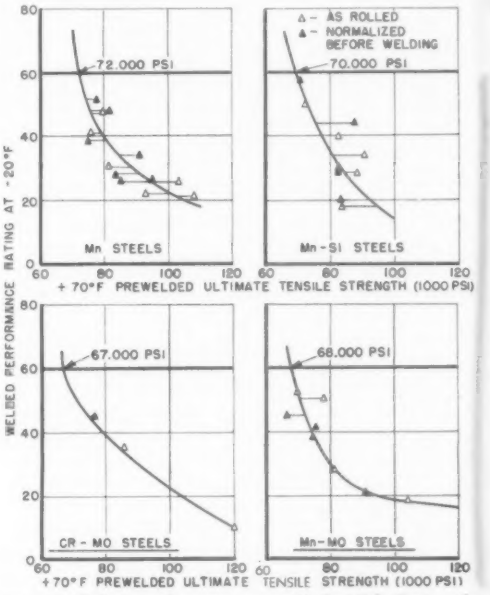


Fig. 12 Relations between prewelded +70° F. tensile strengths and low temperature welded performance for Mn, Mn-Si, Cr-Mo and Mn-Mo steels

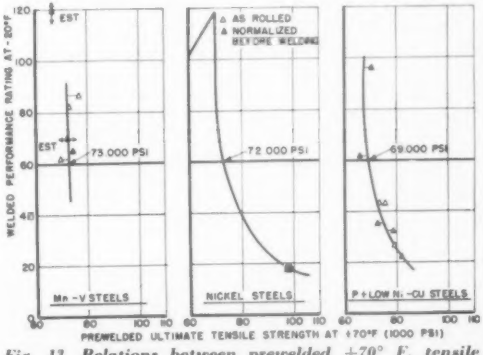


Fig. 13 Relations between prewelded +70° F. tensile strength and low temperature welded performance for Mn-V, Ni and P-Ni-Cu steels

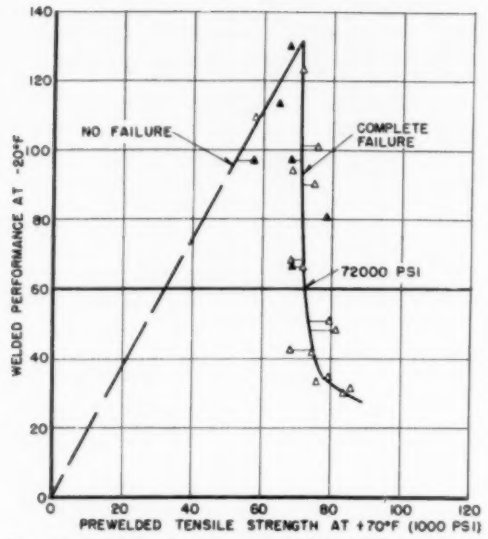


Fig. 14 Relation between prewelded +70° F. tensile strength and welded performance at −20° F. for Mn-Ti steels

and then abruptly falls with continuous increases in maximum plate hardness for each composition family.

INFLUENCE OF BENDING TEMPERATURES

Low-temperature prewelded tensile properties of the steels were not reported. However, it is known that in general steel strength increases with decreased temperature. By relating the specific welded preformance at −20° F.; that is, the energy absorbed at −20° F. compared to the energy absorbed by the referenced unfractured 0.20% carbon steel at +70°F., to the normal temperature tensile strength of the steels, a series of interrelationships is obtained as shown in Figs. 11 to 14, inclusive. No data are available for the prefracture portion of the curves for most of the alloys at −20° F., but it is possible to establish the maximum normal temperature tensile strengths corresponding to a minimum welded performance rating of 60. This rating coincides with a condition under which the specimen withstood maximum load before failure, Fig. 2. Other limits could be chosen without disturbing the relative validity of the comparisons. The entire performance-strength curves are now displaced to the left as compared to the corresponding relations at room temperature, Figs. 3 to 8. This means that, even for securing a welded performance (60) which is lower than that for normal temperatures (100), slightly lesser maximum initial prewelded tensile strengths at normal temperatures are required.

Similar comparisons can be made for the yield strength and hardness values, as was the case at room temperatures, using the same methods. The limits for maximum tensile strength, yield strength and pre- and postwelded hardness, corresponding to an average minimum welded performance of 60, derived by the same methods described for normal temperature conditions are listed in Table 4.

The same general relations thus exist between welded performance at −20° F. and the +70° F. plate properties as were found for the +70° F. bend tests except that to obtain the same welded performance the magnitudes of maximum plate strength and hardness must be less. The welded performance is lesser at −20° F. than at +70° F. for higher identical compositions and higher at −20° F. than at +70° F. for lower identical compositions; reflecting the shifting influence of plate strength and notch ductility. For all but the very low compositions, testing at −20° F. lowers welded performance so much that the minimum ultimate strength range for maximum welded performance can be determined for carbon and Mn-Ti steels only, Figs. 11 and 14. With them the required ultimate strength at room temperature is 7000 psi. lower than for bend tests at +70° F. When service at subzero temperatures is anticipated for welded structures in which notch effects are present adjacent to the weld, steels having yield and ultimate strengths 5 to 10,000 psi. lower than those used for service at toom temperature for the same composition type should be used. For the same welded performance at −20° F. higher yield and ultimate strengths are obtainable for the low alloy than for the plain carbon steels, Table 4. For low-temperature service normal temperature joint properties must be ignored and the comparisons should be made upon the low-temperature joint characteristics.

Table 4—Maximum +70° F. Prewelded Physical Properties and Postwelded Hardness for a Minimum Welded Performance of 60 at —20° F. Under Test Conditions

Relative order	*Alloy type*	*Plate tensile strength, psi.* — *Yield*	*Ultimate*	*Average value of yield to ultimate ratio*	*Hardness (DPH)* — *Prewelded*	*Maximum in heat-affected zone*
1	Mn-V	53,000	73,000	0.727	150	210
2	Mn-Ti	51,000	72,000	0.708	150	185
3	Ni	50,500	72,000	0.701	155	218
4	C-Mn (Mn > 0.75)	44,700	72,000	0.620	144	223
5	Cr-Mo	44,300	67,000	0.660	150	216
6	P + low Cu-Ni	44,000	69,000	0.638	152	234
7	Si-Mn	43,300	70,000	0.619	145	200
8	Mn-Mo	43,000	68,000	0.633	154	210
9	Carbon (Mn < 0.75)	38,800	66,000	0.588	137	200

INFLUENCE OF CHEMICAL COMPOSITION

It has been demonstrated that at both normal and subzero temperatures the welded performance of joints under notch stresses from any composition type can be related directly to the normal temperature yield and tensile strengths of the prewelded plate, as well as to the pre- and postwelded hardness. All four of these properties are directly related to chemical analyses for a given prewelded rolling condition. This is most readily shown by the carbon steel data in Fig. 15. The analysis of the steel is therefore the primary variable which influences the welded performance for each rolling condition since things related to the same thing are related to each other.

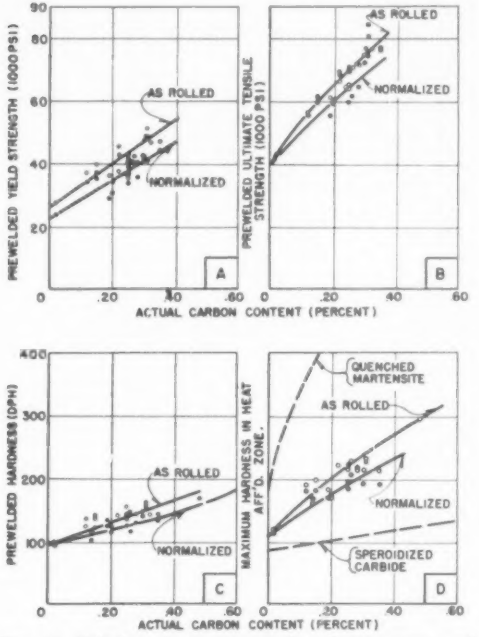


Fig. 15 Relations between actual carbon content and steel properties (carbon steels, +70° F.)

The carbon vs. plate properties for the carbon steels contain considerable scatter because the plates were produced on different mills under varying rolling conditions. The locations of the maximum hardness data within the limiting parameters, Curve *D*, shows the welding procedure employed caused hardening but only to a relatively mild extent. The welding procedure may thus be termed favorable.

Figure 16 shows that for the lower carbon contents the angle of bend for the carbon steels at normal temperatures is a constant, that is, under the imposed conditions, no failure normally occurs at +70° F. As the actual carbon content approaches 0.25% for as-rolled plates and 0.30% for normalized plates the angular deformation abruptly drops to lower values and reaches very low values for the higher carbon contents. At −20° F. the point of departure from high deformation was at 0.20% carbon and some fractures were occurring even for the 0.02% carbon iron.

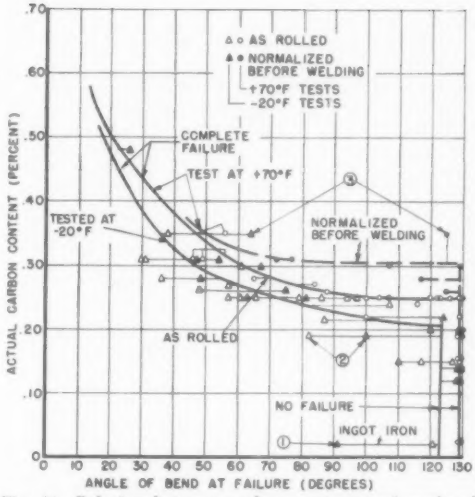


Fig. 16 Relation between carbon content and angle of bend for plain carbon steels

Figure 17 shows that at normal temperatures the maximum load resisted by the bend specimens first increased and then decreased with increases in the carbon content of the plain carbon steels. The rising load is associated with the increasing material strength, as shown in Fig. 15, and the falling load with a progressive tendency toward failure on the rising load of the load-deflection diagram, as illustrated in Fig. 2.

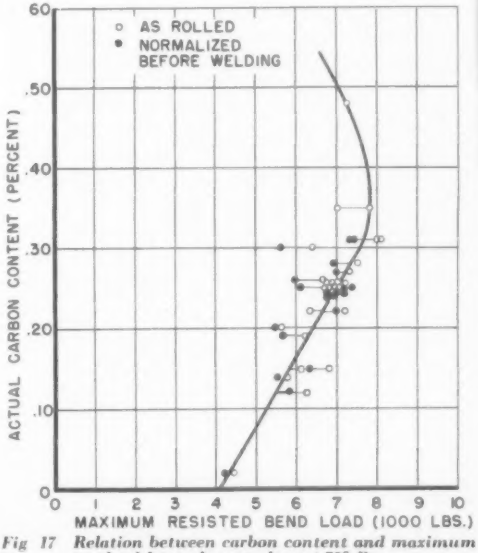


Fig. 17 Relation between carbon content and maximum load for carbon steels at +70° F.

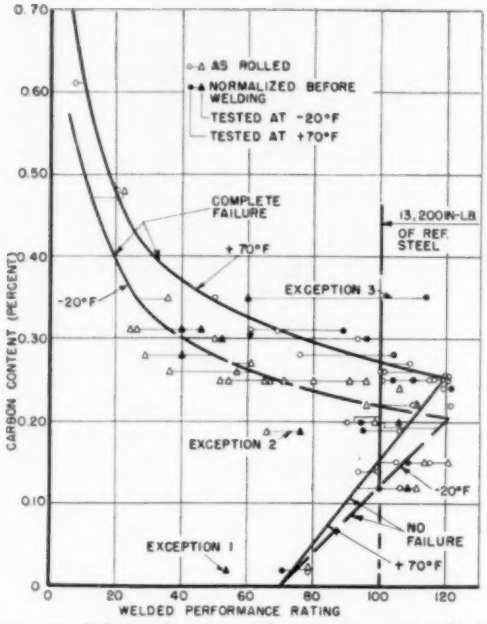


Fig. 18 Relation between carbon content and welded performance of carbon steels

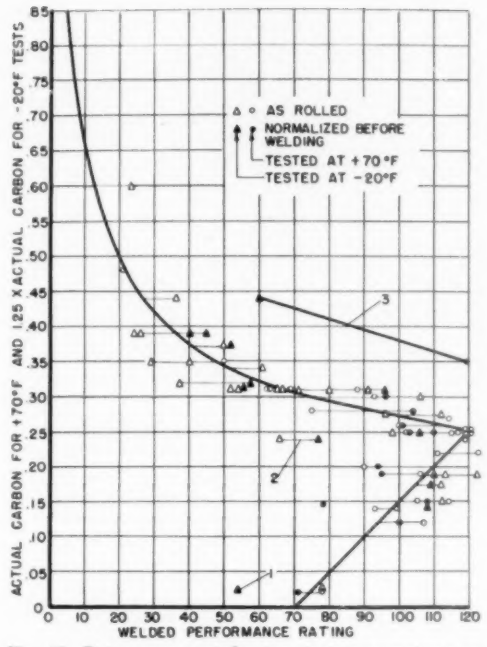

AS ROLLED
NORMALIZED BEFORE WELDING
TESTED AT +70°F
TESTED AT -20°F
ACTUAL CARBON FOR +70°F AND 1.25 X ACTUAL CARBON FOR -20°F TESTS
WELDED PERFORMANCE RATING

Fig. 19 Data agreement for two test temperatures on carbon steels

The energy absorption values follow a composite of the maximum load and angle at rupture curves. The absorbed energy increases gradually as the carbon increases from low values; reaches a maximum at 0.25% carbon content for normal temperatures and then abruptly decreases to very low values for high carbon contents, as shown in Fig. 18. A corresponding relation exists for the low temperature data except at the low carbon contents the absorbed energy tends to rise with increased carbon more rapidly and the break point is reached sooner. For all comparable higher carbon contents the performance rating is then less at low temperatures than at normal temperatures, that is, the absorbed energy at fracture is less. Figure 18 shows that an optimum carbon content exists for both temperatures.

Each composition type follows an analysis-performance pattern similar to that of the carbon steels. For example, high manganese, phosphorus or nickel steels become brittle; lesser but optimum additions of the same alloying elements provide joints of high strength and ductility, and very low alloy additions provide highly ductile joints of lesser strengths and capacities to absorb energy. In all cases, the results are influenced by the amount of carbon present.

DETERMINATION OF EQUIVALENT CARBON CONTENTS

Carbon

There is an optimum carbon content for obtaining maximum energy absorption in the carbon steel specimens prior to fracture; namely from 0.15 to 0.27% for normal temperature tests and 0.12 to 0.22% at −20° F., as shown in Fig. 18, for steels containing less than 0.75% manganese.

Carbon is the essential element in steel. Its effect upon welded performance can be conveniently taken as a reference. The carbon effectiveness factor at +70° F. is therefore taken as unity. In Fig. 18 it is shown that the low temperature performance vs. carbon content curve is depressed about 20%, on the average, below the room temperature relation. By using a 1.25 factor for carbon effect at −20° F. with respect to its effect at +70° F. the two curves are made to superimpose one upon the other. The composite plot from the use of the two factors is shown in Fig. 19. The pattern for all conditions with three heat exceptions is

Table 5—Relative Influence of Alloying Elements on Welded Performance of 1/2-in. Plate Subject to Concentrated Stresses

Element	*Effectiveness factor relative to carbon at +70° F. for tests at:* +70° F.	−20° F.	*Relatively increased effectiveness at −20° F. over normal room temperatures, +70° F.*
Carbon	1.00	1.25	1.25
Manganese	0.10	0.13	1.30
Phosphorus	0.86	1.22	1.42
Silicon	0.11	0.26	2.36
Copper	0.03	0.045	1.50
Nickel	0.03	0.045	1.50
Chromium	0.10	0.18	1.80
Molybdenum	0.33	0.37	1.12
Vanadium	0.17	0.00	...
Titanium	(Insufficient data available)		

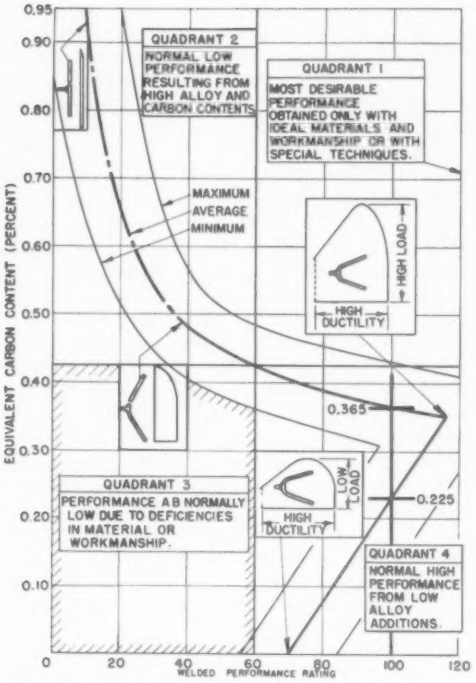


Fig. 20 General relation between welded performance and equivalent carbon content

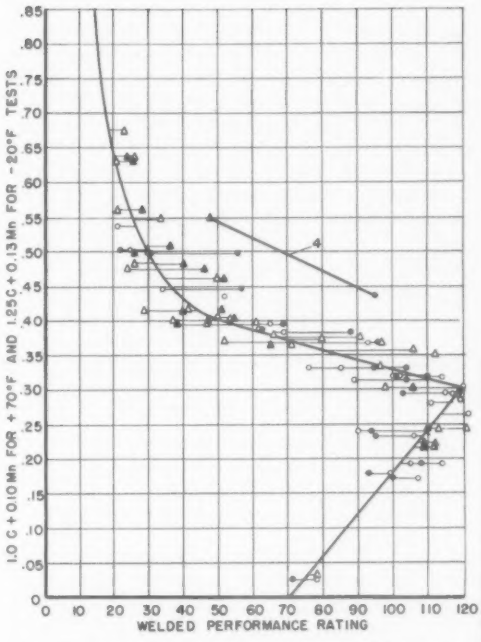


Fig. 21 Data agreement for carbon and C-Mn steels

good considering that the steels were produced under many conditions, were welded in both the as-rolled and normalized conditions, were welded both precooled and at room temperature and were tested at both +70 and −20° F. and contain some variations in silicon and manganese content. The exceptions were the same items which did not conform to the strength patterns in Figs. 3 and 11.

The use of the determined effectiveness multiplying factors shown in Table 5, applied to the quantity of each individual element present, was found in general to place the performance of each group of specimens within the band limits shown by Fig. 20 when the individual element quantities and the listed effectiveness factor products were added up to provide a total resultant equivalent carbon content. Results from both the room temperature and the −20° F. bend tests are separately incorporated within the same band pattern in Fig. 20 by the use of the higher factors shown in Table 5 for the low temperatures. The average optimum calculated equivalent carbon content now falls within the range of 0.225 and 0.365% as shown. This increase from the actual optimum carbon range of from 0.15 to 0.27%, or about 0.085%, is the equivalent contribution of the average 0.51% manganese, 0.017% phosphorus and 0.07% silicon contents of the carbon steels. Within the 0.225 to 0.365 equivalent content range, the average energy absorbed is equal to or more than that of the reference material: that is, of the 0.20% carbon, 30,800 psi. yield, 60,900 psi. ultimate strength steel.

Table 6—Sample Calculations of Equivalent Carbon Content

	Case 1 (Plain Carbon Steel)				Case 2 (C-Mn-P-Cu-Ni Alloy)			
	+70° F. Bends		−20° F. Bends		+70° F. Bends		−20° F. Bends	
Actual analyses	*Factor**	*Product*	*Factor**	*Product*	*Actual analyses*	*Factor**	*Product*	*Factor**	*Product*
C = 0.25	1.00	0.250	1.25	0.312	C = 0.20	1.00	0.200	1.25	0.250
Mn = 0.42	0.10	0.042	0.13	0.055	Mn = 0.66	0.10	0.066	0.13	0.086
P = 0.014	0.86	0.012	1.22	0.017	P = 0.106	0.86	0.091	1.22	0.129
Si = 0.008	0.11	0.001	0.26	0.002	Si = 0.06	0.11	0.007	0.26	0.016
Cu = 0.17	0.03	0.005	0.045	0.008	Cu = 0.42	0.03	0.013	0.045	0.019
Ni = 0.08	0.03	0.002	0.045	0.004	Ni = 0.89	0.03	0.027	0.045	0.040
Cr = 0.04	0.10	0.004	0.18	0.007	Cr = 0.03	0.10	0.003	0.18	0.005
					Mo = 0.00	0.33	0.000	0.37	0.000
					V = 0.00	0.17	0.000	0.00	0.000
Sum = equivalent carbon =		0.316%	...	0.405%	Sum = equivalent carbon =		0.407%	...	=0.545%

* From Table 5.

The upper permissible total analyses or equivalent carbon content for any desired performance level may be made up largely of actual carbon with the addition of little alloying elements or little carbon may be present and the alloy content may be relatively high. The same results are obtained for either condition, within the limits of available data.

Two examples should suffice to illustrate the manner of calculating the total equivalent carbon content for any tested heat of steel; that is, the ordinate of the curve in Fig. 20. These are provided in Table 6. The total carbon equivalents were obtained to suit the performance of the reported welded specimens.

The intercepts of the zero equivalent carbon content, or the pure iron ordinate, with the corresponding strength and hardness abscissae as determined from the carbon steel data were:

Welded performance = 70
Prewelded yield strength = 23,000 psi.
Prewelded ultimate strength = 39,000 psi.
Prewelded hardness (DPH) = 93
Postwelded maximum hardness (DPH) = 108

For the twenty-five reported heats of carbon steel containing less than 0.75% manganese, one heat provided points to the right of the finally established band in Fig. 20 for the normalized condition only. For one heat all specimens were subnormal at −20° F. and for the one very low carbon heat the normalized low temperature bend values were subnormal as also shown in Figs. 11 and 19. All other values, 88% of the heats and 94% of the joints tested, are within the limits of the presented analyses-performance band, Fig. 20.

The corresponding plate properties as obtained directly from the physical properties plots in Figs. 3, 9 and 10 are recorded at the bottom of the list, item 9, in Tables 3 and 4.

For the higher compositions the absence of ductility becomes the important factor. The energy absorbed thus first rises with and then abruptly decreases with increases in carbon content. For the carbon steels each incremental value of carbon contributes 1.25 times as much to the absorbed energy at −20° F. as it did at normal temperatures; favorably in the low analyses ranges and unfavorably in the high analyses ranges. Corresponding maximum physical properties at +70° F. for a minimum welded performance of 60 at −20° F. are shown in Table 4.

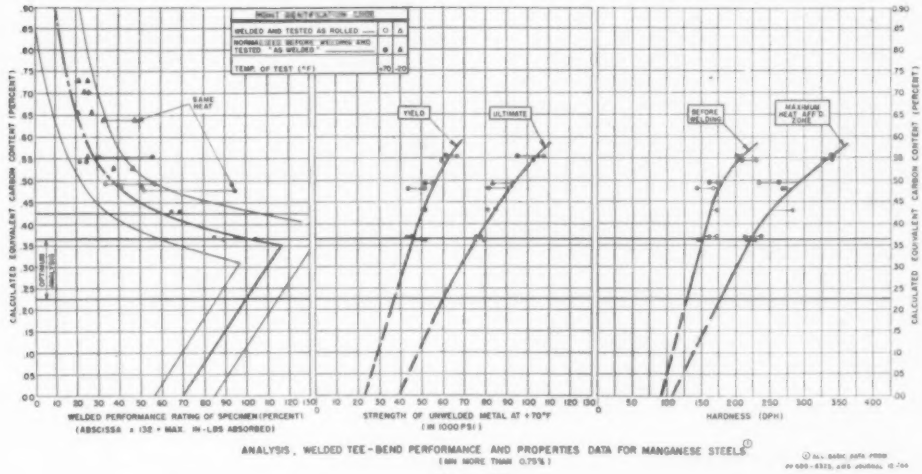
Manganese

The manganese factor was determined by plotting the points for the seven manganese heats containing from 0.85 to 1.62% manganese as in Fig. 21, making the required upward corrections for the manganese influence at both +70 and −20° F. In almost all cases, before applying a manganese correction, the points fell below the Fig. 19 curve established for the carbon steels, which had an average manganese content of only 0.51%. The low side deviation in the ordinates from the curve was the total equivalent carbon effect of the manganese present over the carbon steel group average of 0.51%. The corresponding carbon equivalent of the manganese was thus obtained at each temperature by dividing the appropriate individual ordinate differentials by the corresponding amounts of manganese present above the 0.51% average for the plain carbon steels. It was considered advisable not to use the calculated averages directly but instead to use values which would result in the high performance heats fitting near their corresponding positions at the nose of the curve in Fig. 20. Accordingly factors of 0.10 and 0.13 were used for the two test temperatures. This produced a fit, as shown in Fig. 21 which is essentially acceptable. It does show the generally beneficial effects of preweld normalization of a given analysis.

The relative influence of manganese upon hardness after welding is commonly taken as 0.06 Mn to 0.01 C. This is about the same ratio as determined from the hardness data in the tests under discussion. For the welded joint energy of deformation capacity, however, the effectiveness factors of 0.10 and 0.13 for manganese at normal and −20° F. temperatures, respectively, are more nearly appropriate for conditions which produce uncracked welded joints. This means that the unit influence of manganese is relatively much less than that of carbon. The bend energy data fit the analyses-performance band established for the carbon steels, Fig. 20, when using the described manganese factors, with the exception of two heats in the prewelded normalized conditions. These two items have had their yield and tensile strengths substantially reduced by that treatment, and in accord with Figs. 1, 4 and 12, were subjected to lesser fiber stress.

The optimum strength and hardness values for this composition family are appropriately entered in Tables 3 and 4 as items 8 and 4, respectively. This family composition thus lists as slightly superior to the plain carbon steel for capacity to achieve both strength of metal and tough welded joints, provided the combined carbon, manganese and other elements are maintained below the limits of total analyses shown in Fig. 20 and the plates are produced with the accompanying appropriate strength values. Even so, under severe stress conditions a 50,000 psi. minimum yield point manganese steel, as commonly required by specification for low-alloy high-tensile steels, on the average, cannot be expected to absorb maximum shock values. The high-analyses, high-strength compositions are brittle after the direct welding operation without benefit of pre- or postheating.

After a complete series of determinations for the various element effectiveness factors had been made, as described and listed in Table 5, the corresponding equivalent carbon content vs. welded performance, yield strength, ultimate tensile strength and hardness of the prewelded steel and the maximum hardness of the heat-affected zone after welding were plotted for each composition family. All compositions can be treated in a similar manner. A typical result is shown in



ANALYSIS, WELDED TEE-BEND PERFORMANCE AND PROPERTIES DATA FOR MANGANESE STEELS[1]
(.68% MORE THAN 0.75%)

Figure 22

Fig. 22 for the manganese steels. The variation of the unwelded steel characteristics is not suitably determined by the sum of the products of the several multiplication factors applied to the specific amount of each element present, as determined for the welded specimens. The use of this method of presentation, however, serves to show the continuing upward trend of the related physical properties with increases in compositions for all composition types while the welded performance first progressively increases, and then decreases with continuously increasing total carbon and alloy additions. The strength and hardness curves for each alloy family vary in slope with composition type. The point of origin for these curves is the determined value for a zero equivalent carbon content. The location of the analyses vs. welded performance band, shown in Figs. 20 and 22, is identical to show the conformance and nonconformance to the Fig. 20 band.

Phosphorus

The performance of 4 heats, ranging from 0.075 to 0.110% phosphorus combined with low copper and nickel were reported. Using effectiveness factors of 0.86 and 1.22 at room and −20° F. temperatures, respectively, all as-rolled welded specimens fall within the band established by Fig. 20. Two high side performance exceptions for normalized plate suggest the beneficial effects of preweld normalization for a given analysis, as previously indicated from Figs. 4 and 13. The hardness values increased with total analyses, the change being marked for the maximum postwelding values on the higher analyses.

The average optimum prewelded strength and hardness values for this composition family at room and low temperatures are appropriately listed as the seventh and sixth items in Tables 3 and 4.

The increase in the low-temperature effect of phosphorus is shown by the change to a factor of 1.22 over the normal temperature factor of 0.86 which is a relative increase of 42%. The relatively high magnitudes of the effectiveness factors at both temperatures with respect to carbon show that phosphorus has a strong effect upon welded performance.

Sulphur

Sulphur is not a strengthening element and no performance data were available on variable sulphur steels containing more than 0.047% sulphur. Accordingly no account was taken of the influence of this element in the curve shown in Fig. 20. That curve is therefore applicable only for steels containing less than 0.05% sulphur and is most nearly applicable for average sulphur contents of 0.032%. It is generally accepted that sulphur is not a carbide forming element, that it does not contribute to the strength of the steel, but that its presence in larger amounts may result in weld porosity and hot cracking.

It would be necessary to conduct other supplementary tests to determine the precise effect of this element on the identical comparative basis, but sulphur additions are not beneficial. Single pass fillet welds made with E-6010 electrodes on a high sulphur steel are shown in Fig. 23. Typical longitudinal and transverse inclusion distributions of this steel, a commercial free-machining grade not ordinarily furnished for welding, are also shown. Such a steel falls into a different welding classification, as distinguished from a poor performance class, because it also causes welding operational difficulties and limitations. The restriction of sulphur contents for structural welding applications to less than 0.05% appears to be a wise choice.

Silicon

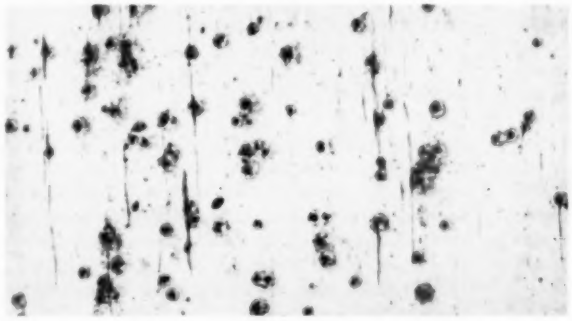
Four heats, ranging from 0.24 to 0.50% silicon content and one with 1.00% Si plus copper and nickel were reported. Since all but one of the first group contain more than 0.75% manganese they may be more precisely classed as silicon-manganese steels. The use of 0.11 and 0.26 effectiveness factors for silicon at +70 and −20°F., respectively, place all as-rolled and all but one set of normalized points within the analyses-performance band shown in Fig. 20. Silicon thus even more than phosphorus changes in relative importance with respect to its potential detrimental influence upon welded performance at lower temperatures. All of the higher analyses were improved somewhat by preweld normalization which usually reduced the ultimate strengths. The corresponding optimum strength and hardness values for these steels are shown in Tables 3 and 4, items 5 and 7.

From the preceding discussions it now becomes possible to relate the results shown in Table 1 into the over-all pattern. The analyses of the plates on which the transverse tests were made were all at or near the nose of the performance-analysis curve. Only small additions of silicon, or of any other alloying element, were thus required to completely change the fracture pattern. If the total analyses would have been either high or low little difference would have been expected from the minor variations in silicon content.

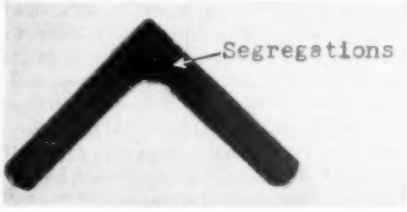
Nickel

Only two strictly nickel steels, containing up to 3.10% nickel, are included in the reported series. The use of 0.03 and 0.045 effectiveness factors for this element at the two temperatures place all points within the common analyses-performance band of Fig. 20. Prewelding normalization only lightly influences the welded performance and the strength and hardness values. The addition of the nickel has substantially increased the prewelded strength of the steel and also its hardness, both before and after welding.

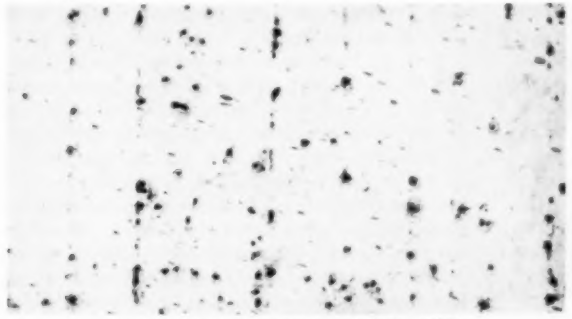
The indicated optimum permissible strength and hardness values for optimum welded specimen performance are listed in Tables 3 and 4, items 1 and 3, to place this family near or at the top of the relative list for uncoated plates when the proper balance for total maximum carbon and nickel is maintained; that is, when nickel is used as a strengthening element in the place of too high quantities of carbon or other alloying elements. The results obtained from these, and all other nickel containing steel data shown in the original paper,[1] are contrary to a popular concept that the mere



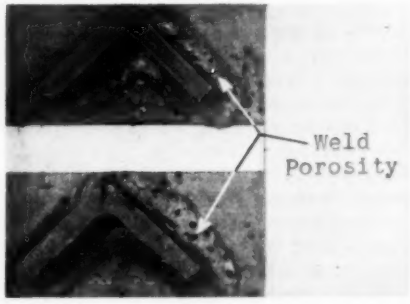
Prewelded longitudinal section unetched. × 100



Contact sulphur print. × 1



Prewelded transverse section unetched. × 100



Single-pass fillet welds. × 0.75

Fig. 23 Conditions encountered in welding high sulphur steels

Check analysis: C, 0.16%; Mn, 0.88%; P, 0.092%; S, 0.29%; N, 0.011%

addition of nickel improves low temperature performance. Poor results may be obtained at both temperatures when the nickel or carbon or their weighted total content is too high.

Copper

With data available from 9 heats, containing more than 0.23% and up to 1.06% copper, the influence of copper can be evaluated only in the presence of other alloying elements. The assignment of the same effectiveness factors as determined for nickel, namely 0.03 and 0.045 for the room and −20° F. temperatures, respectively, place all the as-rolled copper bearing steels in excess of 0.23% copper within the common analyses-performance band shown in Fig. 20. Three high side exceptions occur for normalized plates, all three cases involving plates in which the normalized strengths were relatively low. Since no simple copper steels are included in the study the relative location of the strengths cannot be provided. However, from published data,[2] it is known that uncoated low carbon copper-nickel high yield strength steels containing up to 1.00% copper perform well after welding and testing under the described conditions.

Chromium

Three heats of chromium bearing alloys were reported and the influence of chromium can be evaluated only in the presence of molybdenum. Within this limitation the factors of 0.10 and 0.18 at the two test temperatures fit the common band limits of Fig. 20 fairly well. Again the outstanding exceptions are on the high side for normalized plates. Optimum strength and hardness intercepts are recorded in Tables 3 and 4, items 4 and 5. The relative increase in the low temperature effectiveness factor by 80% over the normal temperature value indicates that higher chromium and chromium bearing steels under severe welded notch and stress conditions tended to become brittle at low temperatures in the as-welded condition. Experience with chromium contents up to 5.00% substantiate the applicability of the listed factors for this element.

Molybdenum

The four reported heats of manganese-molybdenum steels with molybdenum contents up to 0.39%, fit the common performance analyses band shown in Fig. 20, when employing the effectiveness factors of 0.33 and 0.37, respectively, for the two test temperatures. Most of the available data are for the as-rolled condition. The corresponding optimum hardness and strength data are entered in Tables 3 and 4, items 6 and 8.

Vanadium

The three reported heats of manganese-vanadium steels contain only 0.11 and 0.12% vanadium. These quantities are so low that it is impossible to depend upon any obtained effectiveness factors. The performance band is satisfied by the use of 0.17 and 0.00 factors at the two test temperatures. The strength intercepts in Figs. 7 and 13 place this family composition at or near the top of the list of preferred steels for good welded performance, as shown in Tables 3 and 4, items 2 and 1. At low temperatures the performance of this family composition is exceptional for a high yield strength material. The use of a zero or other low factor of effectiveness at the low temperatures is an exception to the other elements studied. Since vanadium acts as a deoxidization and as a grain refining agent, as well as a strengthening agent, it is possible that these are counterbalancing tendencies.

Titanium

Precise evaluation of the relative influence of titanium with respect to carbon was impractical because of the low quantities of titanium used. From performance vs. prewelded strength curves shown in Figs. 8 and 14 it was possible to directly determine the range of most desirable tensile properties. The determined range indicates that this family composition, properly produced, is high on the list for good welded performance as shown in Tables 3 and 4, items 3 and 2.

Other Elements

In a similar manner it is possible, with proper data, to evaluate the relative influence of each of the other alloying elements, such as aluminum, columbium, nitrogen, tin, zirconium, etc. In fact the transient presence of one or more of these or other elements may commonly influence the results obtained from a heat in which the existence of such elements was not considered.

Influence of Nonisolated Variables

Welded performance was shown to relate at both test temperatures to prewelded ultimate and yield strengths, and to prewelded hardness and maximum hardness after welding, for each composition family. All these reference criteria occasionally fail to explain a particular performance value obtained. This indicates the existence of other transient variables such as in the welding or testing conditions, nonuniformity of inclusion content and of their distribution (which were not reported), variations in microstructure, a shifting influence of grain size, the presence of unsuspected alloying elements, or a combination of these and other factors.

The performance of 91% of all specimen groups tested is, however, accounted for on the basis of composition, after the application of the element effectiveness factors shown in Table 5, as calculated in Table 6, and applied to the band pattern of Fig. 20. Almost all of the defections from that pattern are high side exceptions obtained from prewelded normalized plates.

SUMMARY

1. For a fixed set of conditions, the relative influence of each alloying element upon welded performance may be evaluated with respect to that of carbon, Table 5, at both normal and subzero temperatures.

2. The accumulative reduction of the contributing influence of each alloying element relative to that of carbon (Table 6) results in a total equivalent carbon content which, when related to welded performance (Fig. 20) provides a basis for judging the probable performance of any particular steel when welded and tested under identical conditions.

3. For carbon, manganese and all other alloying elements investigated, the specific influence of each additional increment of alloy content depends upon the prior total carbon and alloy content.

4. Alloying elements such as silicon and phosphorus tend to reduce welded joint ductility under concentrated stress conditions particularly at subzero temperatures, more rapidly than they tend to increase hardness. This accounts for the simultaneous occurrence of low maximum hardness and low capacity of welded joints to absorb energy for steels high in phosphorus and silicon contents, particularly at subzero temperatures.

5. High orders of normal temperature welded performance can be obtained with any one of the nine composition families reported. The important factor is the magnitude of the corresponding permissible strengths of the unwelded steel.

6. For combined high yield strength and high welded performance, carbon as an alloying agency is the least desirable of the several alloying elements investigated; that is, for a given high welded performance it requires the lowest upper limit on yield strength.

7. Low-alloy steels, wherein both the total composition and plate strengths are within appropriate limits, provide the highest available yield strengths together with high welded performance under conditions of concentrated stress, particularly at low temperatures.

8. All welded high carbon and the higher alloy steels tested are brittle under the test conditions investigated. The use of the lower alloy additions is economically and strategically desirable and such usuage results in better welded joints. This observation is based upon as-welded joint performance, without benefit of preheat.

9. Availability of check analyses, yield and ultimate strengths, pre- and maximum postwelded hardness and inclusion and microstructure data make an isolation of the cause of the deviation from the average experience possible. Conversely control of these factors plus control of welding conditions should provide control over the welded performance.

10. Prewelded yield and ultimate strengths and prewelded and postwelded hardness progressively increase with increased carbon and alloy contents, whereas welded performance first increases and then decreases with increased compositions.

11. The specific conclusions drawn from the performance of welded $^1/_2$-in. thick plates are not directly applicable to other plate thicknesses involving different thermal, stress and rolling conditions. For conditions of similarity proportionate results may be expected. More data are needed for many of the composition types and for other plate thicknesses and for other thermal and stress conditions.

12. The established optimum limits of tensile properties for best welded performance do not necessarily correspond to existing steel specifications.

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3. U. S. Patent #2,406,076.

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